Chapter 1: Traumatic Brain Injury and Mild Traumatic Brain Injury

Definition

The National Institute of Neurological Disorders and Stroke (NINDS) defines traumatic brain injury (TBI) as a type of acquired brain injury (ABI) that can occur when a sudden trauma causes the brain to be damaged (NINDS, 2009, http://www.ninds.nih.gov/disorders/tbi/tbi.htm). Bruns and Hauser (2003) define TBI as “an alteration in brain function that manifests as confusion, altered level of consciousness, seizure, coma, or focal sensory or motor neurologic deficit resulting from blunt or penetrating force to the head” (p2). TBI is further classified according to severity of injury. The Glasgow Coma Scale (GCS) score is a measure of injury severity and coma or level of consciousness (Teasdale & Jennett, 1974). The GCS measures the individual’s best motor, eye opening and verbal responses, with scores ranging from 3 to 15. MTBI is classified as a GCS score of 13-15, moderate TBI as a GCS score of 8-12, and severe TBI as a GCS score of 3-8.

Post Traumatic Amnesia (PTA) is another parameter used to index TBI severity. PTA can be defined as the period following brain injury that the individual is later unable to remember (Ponsford et al., 2004; Gronwall & Wrightson, 1980). PTA is considered to last until the individual is able to record continuous memories (Ponsford et al., 2004). According to conventional criteria, a PTA duration of less than 5 minutes denotes a very mild TBI; PTA duration of 5-60 minutes denotes a mild TBI; PTA lasting between 1-24 hours is classified as a moderate TBI; PTA lasting between 1-7 days is classified as a severe TBI; PTA duration lasting between 1-4 weeks is classified as a very severe TBI; and a PTA duration that lasts longer than 4 weeks is classified as an extremely severe TBI (Teasdale, 1995).

Within the severities of TBI, mTBI is the most common (see below for further discussion on the prevalence of mTBI). The American Congress of Rehabilitation Medicine (ACRM; Mild Traumatic Brain Injury Committee of the Head Injury Interdisciplinary Special Interest Group, 1993) published a set of standard clinical and research criteria for mTBI. The ACRM define mTBI as a traumatically induced physiological disruption of brain function, resulting in at least one of the following: a period of loss of consciousness (LOC) of 30 minutes or less; a GCS score of 13-15 after 30 minutes; PTA not greater than 24 hours; loss of memory for the events immediately prior to or following the accident; any alteration in mental state at the time of the accident (such as feeling dazed, disoriented or confused); and the presence of focal neurological deficit(s) that may or may not be transient. While the ACRM definition is widely used and accepted, it does have some limitations which warrant mentioning. Firstly, a GCS score of 13-15 after 30 minutes post-injury may be problematic as not all mTBI patients would have been assessed medically within this time (Carroll, Cassidy, Holm, Kraus & Coronado, 2004). McCrea (2008) pointed out that the ACRM definition provides a clear upper limit to differentiate between mild and moderate TBI (based on the maximum duration of LOC and PTA and the GCS score), but does not clearly stipulate a minimum threshold for diagnosing mTBI. Specifically the requirement for an alteration in mental state or amnesia for the event can occur in situations that do not result in a brain injury, such as general trauma or psychological stress (McCrea, 2008). As noted by Iverson, Lange, Gaetz and Zasler (2007) this definition incorporates a wide range of injury severity, ranging from feeling dazed or confused for a few seconds to an LOC for up to 30 minutes or a PTA of up to 24 hours.

The World Health Organization (WHO) Collaborating Centre Task Force on mild TBI (Carroll, Cassidy, Holm, et al., 2004), derived criteria for defining mTBI from the ACRM definition and addressed some of the above limitations. The WHO definition allows for a GCS score to be recorded upon the patient's first presentation to healthcare (Carroll, Cassidy, Holm, et al., 2004). While this allows for a more specific definition of mTBI, GCS scores can fluctuate over time and particularly within the mTBI group, there may be great variation between the GCS score soon after injury and that observed when the patient arrives at a healthcare facility (Ruff & Jurica, 1999). The WHO Task Force performed a comprehensive literature search and a review of methodological quality, and recommended that mTBI be defined as:

> …an acute brain injury resulting from mechanical energy to the head from external forces. Operational criteria for clinical identification include: one or more of the following: confusion or disorientation, LOC of 30 minutes or less, PTA of less than 24 hours, and/or other transient neurological abnormalities such as focal signs, seizure, and intracranial lesions not requiring surgery; GCS score of 13-15 after 30 minutes post-injury or later upon presentation to healthcare; these manifestations must not be due to drugs, alcohol, medications, caused by other injuries or treatment for other injuries (e.g. systemic injuries, facial injuries or intubation), caused by other problems (e.g. psychological trauma, language barrier or coexisting medical conditions) or caused by penetrating craniocerebral injury. (Carroll, Cassidy, Holm, et al., 2004, p115).

Epidemiology

In the United States, an estimated 1.7 million individuals sustain a TBI annually and present to healthcare (Faul, Xu, Wald & Coronado, 2010). MTBI is particularly common, accounting for 60-90% of all TBI's (Tate, McDonald & Lulham, 1998; Bruns & Hauser, 2003;

Cassidy et al., 2004; Sterr, Herron, Hayward & Montaldi, 2006; Moore, Terryberry-Spohr & Hope, 2006). From this it can be extrapolated that in the US there are 1.2 - 1.5 million mTBI's sustained each year. A study of TBI-related hospitalisations in Australia during the 2004-2005 period revealed that 9669 individuals were admitted with concussions of varying severities, of which 60% were recorded as having a concussion (not further specified) or a LOC of 30 minutes or less (Helps, Henley & Harrison, 2008). Incidence figures for mTBI are commonly considered to be an underestimation due to the number of mTBI patients who do not present to healthcare facilities (Summers, Ivins & Schwab, 2009). A population-based survey of mTBI in the US found that 25% of those reporting having suffered a brain injury did not seek any medical treatment, 14% were treated in clinics or offices, 35% were treated in an emergency department, and only 25% were hospitalised (Sosin, Sniezek & Thurman, 1996). Tate et al. (1998) also raised the possibility that hospitalised TBI cases may be overlooked in incidence studies due to poor injury classification upon admission. Additionally, it is reasonable to expect that differing criteria for defining mTBI among studies may result in different incidence figures reported. Regardless of the specific mTBI incidence figures, the economic cost of mTBI is substantial. It is estimated that the direct hospital cost of mTBI in Australia was $184 million over a one year period (Helps et al., 2008).

Males tend to be overrepresented in the TBI population at all ages, with males being hospitalised approximately two and a half times more than females (Helps et al., 2008; Moore et al., 2006; Bruns & Hauser, 2003; Tate et al., 1998). In terms of age, youths and young adults, typically those in the 15-24 year age bracket, tend to have the highest rate of TBI (Helps et al., 2008; Tate et al., 1998), with those aged 0-4 years and those aged 65 years and older also being at increased risk

(Faul et al., 2010). Individuals living in areas of socioeconomic deprivation or with lower socioeconomic status are also at a higher risk for sustaining a TBI (Bruns & Hauser, 2003; Kraus, Fife, Ramstein, Conroy & Cox, 1986).

Neuropathology of mTBI

A number of researchers have attempted to determine the minimum threshold of force required for mTBI to occur. When the brain is subjected to only linear acceleration, estimates of the minimum threshold for mTBI have varied from 70g-100g (McCrea, 2008; Pellman, Viano, Tucker, Casson & Waeckerle, 2003; Ono & Kanno, 1996). However, when the brain is subjected to rotational forces in addition to linear acceleration, this threshold is reduced (McCrea, 2008). Recent work by Guskiewicz and Mihalik (2011) examining athletes following high impact to the head (greater then 90g) found these athletes often did not exhibit symptoms of concussion (such as declines in balance or cognition). Guskiewicz and Mihalik concluded that is very difficult to specify a minimum threshold for mTBI.

The centripetal theory of injury severity.

This centripetal theory delineates the process of cerebral concussion on a continuum from mild to severe (Ommaya and Gennarelli, 1974). It applies to acceleration/deceleration injuries, and it is hypothesised that in cases which result in some level of unconsciousness, the primary injuries to the brain will be more severe in the cortical and subcortical regions than in the rostral brain stem. This theory also states that damage to the rostral brain stem is not seen in isolation but rather occurs in addition to diffuse damage to the brain. Additionally, while confusion and memory disturbance may be seen following injuries that do not result in any LOC, the reverse should never be seen (i.e. LOC without any post-injury confusion or memory disturbance). Finally, the temporal lobes and limbic pathways are more vulnerable to damage than is the mesencephalon (Ommaya & Gennarelli, 1974).

Cerebral concussion is thus defined as:

> …a graded set of clinical syndromes following head injury wherein increasing severity of disturbance in level and content of consciousness is caused by mechanically induced strains affecting the brain in a centripetal sequence of disruptive effect on function and structure. The effects of this sequence always begin at the surfaces of the brain in the mild cases and extend inwards to affect the diencephalic-mesencephalic core at the most severe levels of trauma (Ommaya & Gennarelli, 1974, p 637-638).

The neurometabolic cascade.

MTBI results in neurons and neural systems becoming dysfunctional (Iverson, et al., 2007). The neurometabolic cascade is the process of events which occur within the brain following biomechanical injury. Immediately after injury there is an abrupt and indiscriminate release of neurotransmitters and ionic fluxes in the brain (Giza and Hovda (2001). The N-methyl-D-aspartate receptor is activated, which allows calcium to enter a cell (Barkhoudarian, Hovda & Giza, 2011) with a simultaneous efflux of potassium. The cellular physiology of the brain is impacted by these ionic shifts.

The acute phase post-injury involves the adenosine triphosphate-dependent sodium-potassium pump working harder in an attempt to restore the neuronal membrane to its ordinary potential. This pump requires additional adenosine triphosphate, which prompts an increase in glucose metabolism (Barkhoudarian et al., 2011), which can occur for up to 4 hours in distant brain regions (Samii, Lee & Hovda, 1998, in Giza & Hovda, 2001). The higher glucose requirement is met by an increase in glycolysis, which increases lactate production. Increased lactate production occurring simultaneously with decreased lactate metabolism results in the accumulation of lactate which can cause neuronal dysfunction in a number of ways including acidosis, membrane damage, alterations in blood-brain permeability, and cerebral oedema (Barkhoudarian et al., 2011; Gardiner, Smith, Kagstrom, Shohami & Siesjo, 1982; Kalimo, Rehncrona, Soderfeldt, Olsson & Siesjo, 1981). The discrepancy between increased glucose metabolism and reduced cerebral blood leaves the brain in a vulnerable state and less able to respond to further injuries.

After the acute phase glucose metabolism is depressed for 2 - 4 weeks (Bergsneider et al., 2000) or in the case of more severe TBI, a number of months (Barkhoudarian et al., 2011). Calcium levels remain elevated for up to four days (; Cortez, McIntosh & Noble, 1989; Fineman, Hovda, Smith, Yoshino & Becker, 1993; McCrea, 2008; McIntosh, 1993; Osteen, Moore, Prins & Hovda, 2001) which can impair neural connectivity, disrupt neurofilaments and microtubules and result in cell death; however up to 50 - 60% of the affected neurons have the potential to be saved through intervention (Meythaler, Zafonte, Lombard & Reddy, 2007). Magnesium levels are also reduced following TBI, and can remain so for up to four days (Dhandapani, Gupta, Vivekanandhan, Sharma & Mahapatra, 2008; Vink, Faden & McIntosh, 1988; Vink, McIntosh, Demediuk & Faden, 1987), resulting in impaired glycolytic and oxidative generation of adenosine triphosphate, which can unblock N-methyl-D-aspartate receptor channels causing more influx of calcium (Giza & Hovda, 2001).

Difficulties in memory and cognition after mTBI may be due to dysfunctional excitatory neurotransmission, including the glutamatergic (N-methyl-D-aspartate), adrenergic and cholinergic systems (Giza & Hovda, 2001). Animal studies have demonstrated that mTBI can result in impaired neuronal plasticity in the hippocampus (D'Ambrosio, Maris, Grady, Winn & Janigro, 1998; Sanders, Sick, Perez-Pinzon, Dietrich & Green, 2000; Sick, Perez-Pinzon & Feng, 1998); however the generalisability of these results to human cases is unclear. The physiological disturbances after mTBI including metabolic perturbations, changed blood flow, axonal damage, and abnormal neural activation render the brain less functional and more vulnerable to repeat injury (Barkhoudarian et al., 2011). It is unclear whether the vulnerability for repeat injury decreases over time.

Sequelae

Cognitive issues.

Meta-analytic studies examining cognitive functioning of acutely injured mTBI patients have reported that deficits typically resolve after approximately three months (Belanger, Curtiss, Demery, Lebowitz & Vanderploeg, 2005; Dikmen, Machamer & Temkin, 2001; Frencham, Fox & Maybery, 2005; Ponsford et al., 2000; Raskin, Mateer & Tweeten, 1998; Schretlen & Sharipo, 2003; Vanderploeg, Curtiss & Belanger, 2005).

Acute effects.

Three meta-analyses have been conducted examining the acute effects (i.e. less than three months post-injury) of mTBI on cognitive functioning. Each meta-analysis found support for a significant overall effect size for mTBI in the acute phase post-injury. Frencham et al. (2005) reported an overall weighted g effect size of 0.33 (SD = 0.24). Belanger et al. (2005) compared unselected and litigating samples and found overall effect sizes of 0.52 and 0.63 respectively. These values represent similar effect sizes for each group. Schretlen and Shapiro (2003) divided their results into 4 time periods post-injury, and found overall effect sizes of -0.413 (for <7 days post-injury), -0.290 (7-29 days post-injury), -0.078 (30-89 days post-injury), and 0.044 (>89 days post-injury). All of these studies reported that overall effect sizes reduced to be not significantly different from zero by three months post-injury. Examination of the recovery of cognitive functioning over time revealed that mTBI patients tend to show an exponential recovery, with rapid initial recovery which later becomes more gradual (Schretlen & Shapiro, 2003). Examination of specific cognitive domains by Belanger et al. (2005) revealed significant effect sizes in global cognitive functioning (d = .29), attention (d = .53), executive functioning (d =.21), a verbal/nonverbal fluency composite (d =.81), memory acquisition (d =.37), delayed memory (d =.96), language (d =.64), and visuospatial skills (d =.48). It is important to note that the process of clustering neuropsychological data into domains can be criticized as no neuropsychological test is a pure measure of only one domain (Frencham et al., 2005).

Two well-designed studies both reported slower information processing speed for mTBI patients as compared to trauma controls when assessed an average of between 4.5-7 days post-injury (Landre, Poppe, Davis, Schmaus & Hobbs, 2006; Ponsford et al., 2000). In addition, Landre et al. (2006) also found deficits in divided attention, memory and sustained attention tasks in their mTBI group when compared to trauma controls when tested a mean of 3.87 days post-injury. These differences were not related to pain severity or level of emotional distress (Landre et al., 2006). Ponsford et al. (2000) followed their participants up at three months post-injury and found that this deficit had resolved to be at a comparable level to that of the control group, even in patients who continued to report ongoing subjective difficulties and post concussion syndrome (PCS) symptoms. Dikmen et al. (2001) found different neuropsychological impairments depending on how mTBI was defined. Utilising a definition which incorporated only a GCS of 13-15, the authors found deficits in memory and concentration at one month post-injury. However, a more stringent definition involving GCS of 13-15, PTA < 24 hours, normal head CT scan and time to follow commands of less than one hour resulted in only deficits in memory at one month post-injury.

A number of other studies have also examined the acute cognitive effects post-mTBI; however methodological flaws such as small sample size (Brooks, Fos, Greve & Hammond, 1999) lack of an appropriate (i.e. trauma) control group (Brooks et al., 1999; King, 1996; Mathias, Beall & Bigler, 2004; Voller et al., 1999), and lack of a strict mTBI definition (Brooks et al., 1999; King, 1996) limit the generalizability of the results of these studies.

Long-term (>3mths) effects.

A number of reviews have been conducted examining the cognitive outcome following mTBI at least three months post-injury. Comparisons of mTBI and controls revealed overall effect sizes of .07 to .54 (Belanger et al., 2005; Binder, Rohling & Larrabee, 1997; Frencham et al., 2005; Schretlen & Shapiro, 2003). When individual cognitive domains were assessed, significant effect sizes were reported for attention (Binder et al., 1997), manual dexterity, cognitive flexibility (Zakzanis, Leach & Kaplan, 1999), delayed memory and a verbal/nonverbal fluency composite (Belanger et al., 2005). Studies which included referred samples (i.e. individuals who reported difficulties post-mTBI) tended to report larger effect sizes than those which focused on unselected samples. Belanger et al. (2005) examined litigating, non-litigating clinic-based, and non-litigating unselected samples. They found that the litigating and non-litigating unselected groups had similar cognitive performances for the first 90 days post-mTBI; however the cognitive performance of the litigating group declined for up to three months post-mTBI, while the non-litigating unselected group improved to be similar to controls (Belanger et al., 2005). Effect sizes were similar for studies that did and did not involve validity testing in litigating samples, and in addition effect sizes in this post-acute phase were similar for litigating and clinic-based samples who were not involved in litigation, suggesting that the poorer cognitive performance seen for litigating samples may not have been due to poor effort (Belanger et al., 2005). While this meta-analysis provides more detailed information regarding long-term cognitive functioning following mTBI, the question of why litigating patients have a significantly different profile as compared to unselected samples remains unanswered. The large proportion of mTBI patients who go on to pursue some form of compensation-seeking render this an issue that warrants further investigation.

Uncomplicated versus complicated mTBI severity.

The question of whether mTBI's with different scores on measures such as LOC, PTA and GCS result in different cognitive profiles has been examined in a number of studies. The cognitive functioning of mTBI patients with no LOC versus those with a brief LOC has been found to be similar in a number of studies (Carroll, Cassidy, Peloso et al., 2004; Hanlon, Demery, Martinovich & Kelly, 1999; Iverson, Lovell & Smith, 2000). However, within a group of concussed football players, those who reported PCS symptoms lasting more than 15 minutes performed more poorly on a task of information processing speed than did those whose symptoms lasted less than 5 minutes (McCrory, Ariens & Berkovic, 2000). Comparisons of complicated and uncomplicated mTBI, (based on the presence or absence of cerebral CT abnormalities) have been examined in a number of studies. Uncomplicated mTBI patients have been found to outperform complicated mTBI patients on tasks of verbal and visual memory (Lange, Iverson & Franzen, 2009; Williams, Levin & Eisenberg, 1990), processing speed, verbal fluency (Williams et al., 1990), and speech and language tasks (Borgano, Prigatano, Kwasnica & Rexer, 2003). Kashluba, Hanks, Casey & Millis (2008) found that their complicated mTBI group continued to demonstrate cognitive impairments at one year post-injury, suggesting that this group may be more similar in outcome to moderate TBI group rather than to uncomplicated mTBI group (Kashluba et al., 2008; Carroll, Cassidy, Peloso et al., 2004).

Psychological/psychiatric issues.

The most commonly reported psychological difficulties following an mTBI are depression, anxiety, and post traumatic stress disorder (PTSD). Depression and anxiety have co-morbid rates of up to 85-90% (Gorman, 1996/1997). Statistics from an Australian study indicate that the total prevalence rate of any psychiatric disorder in an mTBI sample was 28.7% and prevalence rate of a new psychiatric disorder following mTBI was 20.8% (Bryant et al., 2010).

Depression.

One difficulty in diagnosing depression following mTBI is the overlap between symptoms of depression and PCS following mTBI, such as decreased energy, reduced initiation, irritability, difficulty making decisions, reduced concentration and memory, sleep disturbances, emotional lability and flat affect (Diagnostic and Statistical Manual of Mental Disorders, fourth edition (DSM-IV), 1994; Rosenthal, Christensen & Ross, 1998). Compared to the prevalence of major depression in the general population (3.2%; Wilhelm, Mitchell, Slade, Brownhill & Andrews, 2003), depressive symptoms are more common in the mTBI population, with rates of between 10% - 39% typically reported (Bryant et al., 2010; Busch & Alpern, 1998; Koponen et al., 2002; Levin et al., 2001; Levin et al., 2005; Meares et al., 2008; Meares et al., 2011).

Busch and Alpern (1998) noted that depression after mTBI was unlikely the sole result of frustration or reaction to lifestyle changes as depression was just as common in mTBI patients who were able to return to their pre-injury work and lifestyle as in those who were not able to do so. The authors suggested that an mTBI may trigger a range of pathophysiological changes which lead to a depressive episode (Busch and Alpern, 1998). In contrast, Bryant et al. (2010) found that the presence of functional impairment (in either the physical or psychological domain) following hospitalised traumatic injury was associated with the development of a range of psychiatric disorders including depression, rather than having sustained an mTBI.

Anxiety.

Among the general population, anxiety is the most common type of mental health disorder, with lifetime prevalence rates of approximately 29% (Kessler et al., 2005). Within the mTBI population anxiety prevalence rates of 23-41% have been reported (Meares et al., 2008; Mooney, Speed & Sheppard, 2005; Moore et al., 2006). Bryant et al. (2010) reported prevalence rates for specific anxiety disorders following mTBI, such as post traumatic stress disorder (12.7%), social phobia (6.1%), panic disorder (7.4%), agoraphobia (14.8%), obsessive-compulsive disorder (3.2%), and generalized anxiety disorder (9.8%). Many individuals who have sustained an mTBI have experienced significant stress as a result of a potentially life-threatening event, the post-injury stress of hospitalisation and pain, and more long-term stressors such as possible loss of job, financial strain, social isolation, cognitive difficulties and possibly involvement in litigation (Epstein & Ursano, in Moore et al., 2006). Anxiety is also an important area to understand within the mTBI population as it has been found to impact upon recovery. Moore, Terryberry-Spohr and Hope (2006) found that mTBI patients with comorbid anxiety perceived themselves to be be cognitively impaired and more seriously injured and were reported to be more functionally disabled than evident on objective measures.

Post-traumatic stress disorder (PTSD).

PTSD is an anxiety disorder that is defined in the Diagnostic and Statistical Manual of Mental Disorders (DSM-IV; American Psychiatric Association, 1994) as involving (a) exposure to a traumatic event that is threatening to well-being; (b). re-experiencing symptoms; (c). avoidance of things associated with the trauma; (d) heightened arousal; and these symptoms must cause impairment to the individual's functioning and persist for at least one month after the trauma.

There is disagreement as to whether PTSD can develop in mTBI patients who cannot fully recall their traumatic event. Some studies claim that mTBI patients who have difficulty recalling the traumatic event, do not become emotionally upset when discussing aspects of the trauma they can remember (Sbordone and Liter, 1995) and that a period of LOC precludes the development of PTSD (Mayou, Bryant & Duthie, 1993). Methodological flaws such as a lack of standardised measures, no blinding of assessors and long periods between trauma and assessment limit the strength of these studies. Other studies have reported prevalence rates of PTSD following mTBI of 13% - 84% (Bryant & Harvey, 1999; Feinstein, Hershkop, Jardine & Ouchterlony, 2000; Harvey & Bryant, 2000; Hickling, Gillen, Blanchard, Buckley & Taylor, 1998; Hoge et al., 2008; Levin et al., 2001). In an Australian study, Bryant et al. (2010) found that mTBI patients were twice as likely to develop PTSD compared to non-head injured trauma controls. It is claimed that PTSD can develop following mTBI through islands of preserved memories (King, 1997; Harvey and Bryant, 2001), pseudomemories based on second-hand information (Bryant, 1996), or implicit processing of the event (Bryant, 2001).

Postconcussion syndrome (PCS).

Both the DSM-IV and the International Classification of Diseases, tenth revision (ICD-10) propose definitions of PCS. The DSM-IV defines PCS as (a) a history of head trauma resulting in significant cerebral concussion; (b) cognitive deficit in attention and/or memory; (c) three or more postconcussion symptoms (fatigue, sleep disturbance, headache, vertigo or dizziness, irritability or aggression, anxiety, depression or affective instability, personality change, or apathy/lack of spontaneity) which occur soon after injury and persist for at least three months; (d) symptoms are of new onset or represent a worsening of pre-existing symptoms; (e) symptoms interfere with social or occupational functioning; (f) symptoms are not better accounted for by any other disorder. The diagnostic criteria for PCS in ICD-10 requires (a) a history of head trauma with

LOC; and (b) three or more of the following: headache, dizziness, malaise, fatigue, noise tolerance; irritability, depression, anxiety, emotional lability; subjective concentration difficulties, memory or intellectual difficulties without neuropsychological evidence of impairment; insomnia; reduced alcohol tolerance; preoccupation with symptoms with hypocondriacal concern and adoption of the sick role.

The incidence of PCS may vary based on which criteria are employed, with the ICD-10 criteria resulting in higher reported prevalence rates (Boake et al., 2005; McCauley et al., 2005). Boake et al. (2004) found limited agreement between the two criteria (kappa = .13) due to the DSM-IV requiring a cognitive deficit (criterion b) and clinical significance (criterion e). It is common in research to classify PCS based on the total number of symptoms endorsed (Gouvier, Cubic, Jones, Brantley & Cutlip, 1992; Wang, Chan & Deng, 2006), the presence of symptom clusters (Bryant & Harvey, 1999; Emanuelson, Andersson, Holmkvist, Bjorklund & Stalhammar, 2003), or a required number and frequency of PCS symptoms (Meares et al., 2011; Meares et al., 2008; Meares et al., 2006; Mooney et al., 2005).

PCS is not specific to mTBI and is commonly observed in chronic pain (Smith-Seemiller, Fow, Kant & Franzen, 2003), depression (Trahan, Ross & Trahan, 2001), personal injury claimants (Dunn, Lees-Haley, Brown, Williams & English, 1995), non-head injured trauma patients (Bryant, 2011; Meares et al., 2008; Meares, Shores, Taylor, Lammél & Batchelor, 2011), and non-injured adults (Wang et al., 2006; Iverson & Lange, 2003; Sawchyn, Brulot & Strauss, 2000). As noted by Meares et al. (2008) the term PCS is therefore somewhat misleading as it incorrectly suggests that PCS symptoms are specifically attributable to a brain injury.

There is some suggestion that female gender (Bohnen et al., 1994; McCauley, Boake, Levin, Contant & Song, 2001; Meares et al., 2008; Meares et al., 2011; Ponsford et al., 2000; Ryan & Warden, 2003), older age (Bohnen et al., 1994; Ryan & Warden, 2003), the presence of other emotional problems (Bohnen et al., 1994; McCauley et al., 2001; Meares et al., 2008; Meares et al., 2011; Ponsford et al., 2000) and higher subjective report of pain (Meares et al., 2008; Meares et al., 2011) are associated with a higher likelihood of developing PCS.

PCS symptoms often resolve within one month post-injury, but a minority of patients continue to report symptoms for months or even years post-injury (Ryan & Warden, 2003). PCS may not merely persist over time but rather change and develop post-injury (Meares et al., 2011).

Headache and PCS.

Headache is one of the more commonly reported PCS symptoms (Martelli et al., 2007; Martelli, Grayson & Zasler, 1999; Mooney et al., 2005; Nampiaparampil, 2008), with incidence rates of 75% - 90% being reported following trauma to the head, brain or neck (Keidel & Diener, 1997, in Martelli et al., 1999; Nampiaparampil, 2008). Up to 44% of head-injured patients continue to experience headaches more than 6 months post-injury (Benedittis & Santis, 1983, in Martelli et al., 1999). Patients with mTBI have a higher prevalence of chronic headache as compared to those with moderate to severe TBI; however the underlying reason for this remains unclear (Nampiaparampil, 2008). Headaches were found to be independently associated with PCS symptoms in a poorly-recovering mTBI sample, even after controlling for depression and non-cephalic pain (Mooney et al., 2005). In a military group mTBI was found to be significantly associated with headache 3-4 months after return from deployment (Hoge et al., 2008).

Pain.

Iverson and McCracken (1997) found that 80.6% of their chronic pain patients who had not sustained a head injury endorsed three or more post-concussive symptoms and 39% additionally reported some cognitive complaint. When compared to an mTBI group, chronic pain patients have been found to endorse a similar number of items on a self-report checklist (Smith-Seemiller et al., 2003); however mTBI patients were more likely to endorse cognitive symptoms while there was a trend for chronic pain patients to endorse more emotional symptoms. In a study of poorly recovering mTBI patients, it was found that non-cephalic pain was significantly associated with PCS symptom reporting even after controlling for depression (Mooney et al., 2005). Meares et al. (2011) found that the subjective report of pain was predictive of PCS both in the acute stage post-injury and at three months post-injury for mTBI and trauma control patients.

Both headache pain and non-cephalic pain have been found to adversely affect attention, memory, executive functioning, processing speed and psychomotor speed (Grigsby, Rosenberg, Busenbark, 1995; Hart, Martelli & Zasler, 2000; Kuhajda, Thorn, Klinger & Rubin, 2002; Martelli, Nicholson & Zasler, 2007; Taylor, Cox & Mailis, 1996). A functional magnetic resonance imaging (fMRI) study of individuals performing an attention-demanding task while receiving and not-receiving painful stimuli suggested that pain has the same effect as an additional cognitive load has on one’s attentional capacity (Seminowicz & Davis, 2007), providing evidence for a mechanism by which pain impacts attention. It has been suggested that the anterior cingulate cortex and the hypothalamic-pituitary-adrenocortical axis are associated with disrupted cognitive functioning due to pain. The anterior cingulate cortex mediates the impact of distress caused by pain through the allocation of attentional resources (Martelli et al., 2007). Anticipation of unpredictable pain symptoms becomes a stressor which repeatedly activates the anterior cingulate cortex and the hypothalamic-pituitary-adrenocortical axis, resulting in disruption in cognitive efficiency (Hart, 2003 as cited in Martelli et al., 2007).

Chapter 2: Litigation in TBI and mTBI

Litigation and compensation-seeking are important areas when evaluating outcome following mTBI. In this paper the term litigation is used to refer to a formal legal proceeding that has involvement from a court of law. Compensation-seeking is used to refer to administrative financial-seeking that does not involve a legal aspect, such as seeking worker's compensation or the disability pension. While there are important differences between these two forms of financial compensation, the two groups are often combined in the literature. In the current paper these two groups will be discussed together, except in instances where important distinctions have been made in the literature or when it is thought that the implications of each may be different for mTBI patients.

It has been reported that either seeking compensation or being involved in litigation can impact upon a number of areas including performance on neuropsychological tests, emotional state, subjective report of complaints and one's ability to return to pre-injury employment levels (Belanger et al., 2005; Lees-Haley et al., 1997; Miller & Donders, 2001; Paniak et al., 2002; Paniak, Toller-Lobe, Melnyk & Nagy, 2000; Schmand et al., 1998; Youngjohn, Davis & Wolf, 1997). There are a range of possible reasons as to why litigation or compensation-seeking can affect these areas. Approximately 24% - 33% of mTBI patients seeking compensation consciously enact or exaggerate impairment (Binder, 1993; Green & Iverson, 2001; Green, Iverson & Allen, 1999; Stulemeijer, Andriessen, Brauer, Vos & Van der Werf, 2007). However other factors such as the stress associated with pursuing litigation or compensation, post-concussion symptoms, or psychological factors (such as depression, anxiety or post-traumatic stress) may also contribute to poor recovery (Stulemeijer et al., 2007; Wood & Rutterford, 2006; Mooney et al., 2005; Miller, 2001). The following section discusses the rates of litigation and compensation-seeking following mTBI; which patients are more likely to pursue litigation or seek compensation; and the effect that litigation or compensation-seeking has on return to employment, cognitive functioning, subjective report of complaints and emotional state.

Incidence of Litigation and Compensation-Seeking in TBI

Reported rates of involvement in litigation and compensation-seeking post-TBI vary as a result of TBI severity and the way in which financial compensation is classified. A number of studies have found that litigation and/or compensation-seeking is more commonly pursued in mTBI patients than in moderate to severe TBI patients (Binder & Rohling, 1996; Green, Rohling, Lees-Haley & Allen, 2001; Tsanadis et al., 2008; Youngjohn et al., 1997); however very few studies report on the incidence of litigation or compensation-seeking for different TBI severity groups. Ownsworth, Fleming and Hardwick (2006) found 64% of their mild to moderate TBI group were pursuing some form of financial compensation, compared to only 43% of their severe TBI group. Youngjohn et al. (1997) reported higher incidence rates, with 100% of the mTBI group pursuing some form of financial compensation, compared to 60% of the moderate/severe TBI group. Importantly, Youngjohn and colleagues noted that only symptomatic mTBI patients who were referred for treatment or evaluation were included, which is likely to have resulted in an inflated litigation rate in this group compared to that seen in unselected mTBI samples.

Reynolds, Paniak, Toller-Lobe and Nagy (2003) conducted a longitudinal study of consecutively admitted mTBI patients and reported rates of financial compensation seeking at the time of injury as well as at both 3 and 12 months post-injury. The authors found that 36.1% of the sample was seeking some form of monetary compensation at an average of 11.98 days post-injury; by three months post-injury 29.9% were continuing to seek compensation; and by 12 months post-injury 28.9% were involved in some type of compensation seeking. No other studies have examined changes in litigation or compensation-seeking over time, and hence it is unclear whether rates change over time in this population. A study of mTBI patients who did not recover as expected found that 61% of injuries occurred within a worker's compensation context, and 27% of patients were involved in litigation (Mooney et al., 2005). The authors noted that these rates of litigation and compensation-seeking are likely to be higher than that commonly observed in mTBI patients, however they are also likely to be in line with the minority of mTBI patients who do not show a typical recovery.

Demographic and Injury Variables Related to Litigation and Compensation-Seeking

A number of studies have examined the relationship between demographic factors and injury-related variables and their ability to predict later litigation or compensation-seeking status post-mTBI, with conflicting results reported. Factors such as age, sex, years of education, pre-morbid socioeconomic status (SES), and ethnicity have all been commonly found to have no predictive value in terms of later litigation post mTBI (Paniak et al., 2002; Reynolds et al., 2003; Wood & Rutterford, 2006). Interestingly, Reynolds et al. (2003) differentiated between patients involved in legal litigation and those involved in administrative compensation-seeking and found that older age and higher socioeconomic status were predictive of administrative seeking post-mTBI.

In terms of injury-related variables, prescription of post-injury pain medication at the time of injury has been found to be predictive of later compensation-seeking in mTBI patients (Paniak, et al., 2002) as has the use of any pain medication up to 12 months post-mTBI (Reynolds et al., 2003). Paniak et al. (2002) noted that this relationship could reflect a higher level of initial injury severity or more post-injury subjective complaints. Other injury-related variables such as time to first memory, length of PTA, length of confusion post-injury (Paniak et al., 2002; Reynolds et al., 2003), and ISS score (Reynolds et al., 2003) have not been found to predict later litigation or compensation-seeking post mTBI. The predictive value of retrograde amnesia duration on later litigation has received conflicting results. Paniak et al. (2002) found no link between retrograde amnesia duration and later litigation; however Reynolds et al. (2003) reported an unusual finding that patients involved in litigation at 12 months post-mTBI reported less retrograde amnesia than did non-seekers. Accurate assessment of retrograde amnesia is difficult as it is (by definition) collected retrospectively and relies on the patient providing detailed information just prior to their accident. It can be difficult for patients to differentiate between what they can actually recall prior to the injury and what they know to have happened based on reports from others and their own assumptions. All of the injury-related variables discussed above have limited variance within an mTBI sample, and this could account for the lack of significant injury-related predictors to later litigation and compensation seeking status.

Effect of Litigation and Compensation-Seeking on Return to Work

The effect of financial incentives on return to work has received relatively little attention. The limited literature that is available provides some support for the hypothesis that seeking or receiving financial compensation post-mTBI has predictive value in terms of later return to work.

A study by Paniak et al. (2000) reported that seeking or receiving financial compensation was the strongest predictor of return to pre-injury work levels in a treated mTBI sample at three to four months post-injury. This strong association could not be explained by any other variables, including severity of brain or other bodily injuries, length of hospital stay, pain medication usage, age, gender, SES, number of previous mTBI's or adverse life events, pre-injury psychological issues, job tenure, or frequency of alcohol usage (Paniak et al., 2000). Specifically the analysis suggested that not seeking financial compensation was more strongly related to returning to pre-injury employment, than seeking financial compensation was of not returning to pre-injury employment (Paniak et al., 2000). While Paniak and colleagues examined a range of important factors which could contribute to the ability to return to productivity, there are others which were not explored. Job status (for example professional versus non-professional; managerial versus non-managerial) and income are two additional factors which have been found to impact on one's ability to return to their pre-injury employment post-mTBI (Boake et al., 2005; Crepeau & Scherzer, 1993; Machamer, Temkin, Fraser, Doctor & Dikmen, 2005). It is important to note that the study by Paniak and colleagues (2000) involved a treated mTBI sample. Despite this fact, their finding that 73.7% of participants had returned to their pre-injury vocational status 3-4 months post-mTBI was similar to the rates reported in a number of non-treated mTBI samples, with reported rates of returning to pre-injury vocation ranging from 66%-88% (Rimel, Giordani, Barth, Boll & Jane, 1981; Englander, Hall, Stimpson & Chaffin, 1992; van der Naalt, 2001).

A longitudinal study by Reynolds et al. (2003) found significant differences in the speed at which mTBI patients returned to work following their injury. The authors found that those not involved in litigation or compensation-seeking shortly after injury had generally returned to their pre-injury employment within one week post-injury. This was in contrast to those who were either involved in litigation or seeking compensation shortly after injury who took a median of approximately six weeks to return to their pre-injury employment (Reynolds et al., 2003). Although small numbers precluded any firm conclusions to be drawn, those individuals who were seeking both administrative compensation as well as being involved in formal litigation shortly after injury showed an even more delayed return to work, with only 50% having returned to their pre-injury employment by 12 months post-injury (Reynolds et al., 2003). While involvement in litigation shortly after injury was predictive of a slower return to employment, pursuing litigation at three months post-injury was found to be an even stronger predictor of a slower return to employment, with those involved in litigation at three months post-injury taking more than three months to return to employment as compared to only four to five days to return to employment in the non-litigating group (Reynolds et al., 2003). Patients still involved in litigation at 12 months post-injury took a median of seven months to return to employment, compared to an average of four days to return to employment for those not in litigation at 12 months post-injury (Reynolds et al., 2003).

Pain, Litigation and Return to Work

The relationship between pain post-mTBI and return to work has received little attention. Uomoto and Esselman (1993, in Paniak et al., 2000) found that 95% of their mTBI sample complained of pain which was significant enough to interfere with at least one activity of daily living. This figure is quite high, considering a review of the literature on pain post-mTBI found an overall average prevalence rate of 75.3% (Nampiaparampil, 2008). As mentioned above individuals experiencing more pain post-injury are more likely to seek financial compensation, and hence pain may be an important mediating factor between litigation status and return to pre-injury employment.

Effect of Litigation and Compensation-Seeking on Cognitive Functioning

Litigation and compensation-seeking and tests of effort.

Litigation status has been found to predict suboptimal performance on tests of effort in a range of studies. Binder (1993) used the Portland Digit Recognition Test, a forced choice measure of recognition memory designed to measure effort, and found that patients seeking compensation performed significantly poorer on this task, compared to those not seeking compensation. Interestingly patients with more mild TBI's were found to perform more poorly than those with more severe brain injuries (Binder, 1993). A number of other studies have similarly found that mTBI patients tend to perform more poorly on tests of effort than do patients who have sustained more severe TBI's (Green & Iverson, 2001; Green, Iverson and Allen, 1999). Therefore there is a substantial amount of support for findings that patients with less severe TBI tend to perform worse on tests of effort when compared to those who have sustained more severe TBI's. This may reflect the fact that mTBI patients are more likely to be involved in litigation or compensation-seeking than patients with moderate to severe TBI's (Bianchini, Curtis & Greve, 2006; Green et al., 2001; Youngjohn et al., 1997). Studies comparing rates of failure on effort tests comparing litigious and non-litigious patients with differing TBI severity would allow further understanding of this issue.

An interesting study by Bianchini et al. (2006) examined the effects of a dose-response relationship between level of compensation and likelihood of displaying poor effort on validity tests. The authors found that mTBI patients were more likely to have hits on malingering indicators than were patients who had suffered a moderate to severe TBI on most measures of effort. On one particular effort measure mTBI patients were ten times as likely to fail as compared to controls. In comparison, moderate to severe TBI patients were only two and a half times as likely to fail as controls (Bianchini et al. 2006). Not only has it been found that a greater amount of potential incentive can result in considerably higher rates of reduced effort on a range of validity tests, but higher potential incentives has also been found to result in an increased likelihood to exaggerate psychiatric symptoms, such as those assessed using the Minnesota Multiphasic Personality Inventory (MMPI-2; Bianchini et al. 2006; Miller and Donders, 2001). This dose-dependent response of reduced effort in relation to litigation suggests that it is the potential financial compensation amount rather than specific factors related to being involved in litigation or compensation-seeking that result in some individuals exaggerating deficits (Bianchini et al. 2006).

The finding that patients involved in litigation or compensation-seeking are more likely to demonstrate poor effort on validity tests has also been found in non-TBI samples. Chronic pain and whiplash patients involved in litigation have been found to fail tests of effort more commonly than their non-litigating counterparts (Gervais, Green, Russell, Pieschl & Allen, 2000; Schmand et al., 1998).

In contrast to the above studies, Stulemeijer et al. (2007) found no association between litigation status and performance on tests of effort; however small sample sizes and the fact that assessments were conducted six months post-injury may have contributed to this finding.

Effort tests are designed so that they are easily passed both by cognitively intact individuals as well as those with cognitive impairment (Green, Flaro & Courtney, 2009). However it is important to note that an individual may fail a test of effort for reasons other than intentionally malingering in the hope of receiving external incentives associated with litigation or compensation-seeking. Evidence of poor effort may be a “cry for help” where the individual is desperate for the recognition and attention for their symptoms; may reflect an individual’s psychological need to be perceived as sick or disabled; may be due to general uncooperativeness; or may be due to a serious psychiatric disturbance (Iverson, 2006). As noted by Iverson (2006) “effort is not a binary phenomenon. It falls on a continuum from very poor to outstanding” (p. 78). Therefore clinicians should always consider a patient’s cognitive ability before assuming poor effort.

Litigation and compensation-seeking and neuropsychological tests.

A recent meta-analysis by Belanger et al. (2005) suggested the neuropsychological profile of mTBI patients involved in litigation may be different to that seen in non-litigious mTBI patients both in regard to the cognitive deficits seen and changes in functioning over time. Belanger et al. calculated effect sizes for each outcome, and found that at less than 90 days post-mTBI unselected samples showed mild deficits across domains, with the largest effect sizes seen for a verbal/non-verbal fluency composite ($d = .89$) and delayed memory ($d = 1.03$), with other cognitive domains ranging from $d = .21$ to $d = .64$. In contrast, litigating mTBI samples had similar effects sizes across all cognitive domains (with effect sizes ranging from $d = .48$ to $d = .52$).

In terms of changes over time, Belanger et al. (2005) reported that at less than 90 days post-mTBI, litigating and unselected samples had similar effect sizes (d = .52 and d = .63 respectively). By 90 days post-injury the effect size for those involved in litigation increased to d = .78, whereas the effect size for unselected samples had reduced to d = .04. Interestingly, effect sizes for those involved in litigation continued to increase to an average of 1three months post-mTBI, whereas unselected samples remained similar to control participants. Belanger et al. further explored the issue of ongoing difficulties in the litigating samples and concluded that this result could not be due to poor effort for two reasons. Firstly, comparison of studies that included a symptom validity measure and those that did not found comparable effect sizes in long-term neuropsychological functioning in mTBI samples. Secondly, after 90 days post-mTBI similar effect sizes were observed for clinic-based (non-litigating) samples and litigating samples (d = .74 and d = .78 respectively). The authors refer to possible explanations for this finding which they were unable to evaluate, including persisting brain dysfunction, and psychological issues such as secondary gain, implicit beliefs/self-expectation, poor coping styles, or emotional reactions to trauma.

A study by Green et al. (2001) compared patients with a known neurological condition and those with an mTBI on tests of effort and cognitive functioning. Patients who had suffered an mTBI and were actively involved in some form of compensation and who were found to fail effort tests were 3.6 times further below the mean score on a range of neuropsychological measures than those in the known cerebral impairment group. This finding suggests that reduced effort may explain some of the poorer performance on cognitive testing in litigious mTBI samples.

Effect of Litigation and Compensation-Seeking on Subjective Report of Symptoms

MTBI patients who go on to seek compensation following their injury are more likely to report more and higher levels of affective/behavioural, cognitive and physical symptoms (as measured by the Problem Checklist from the New York Head Injury Family Interview) than non-compensation seekers (Paniak et al. 2002). A confounding factor which warrants consideration is that of a patient's current mood status. For example, mTBI patients who suffer depression have been found to endorse significantly more post-concussion symptoms than non-depressed mTBI patients (Lange, Iverson & Rose, 2010).

An individual's post-injury functioning is compared to pre-injury functioning as a method of determining whether there has been a reduction in skills or capacities. As objective, independent measures of pre-injury functioning are often limited or non-existent, patients' self-report of their pre-injury functioning must often be used (Lees-Haley et al., 1997). An inherent difficulty with this method is relying on patient's providing an accurate self-report which can be difficult to obtain as an individual's current circumstances, perceptions and general functioning can impact upon their retrieval of past memories and recollections (Lees-Haley et al., 1997). Litigating patients have been found to perceive their pre-injury functioning as more satisfactory and less troublesome, and their current functioning as suboptimal when compared to non-litigating patients (Lees-Haley et al. 1997). Whether this is a conscious and planned decision or reflects a subconscious and unintended way of processing past memories in relation to present functioning remains to be determined (Lees-Haley et al., 1997).

Effect of Litigation and Compensation-Seeking on Emotional State

It makes intuitive sense that the process of seeking compensation or pursuing litigation could result in significant negative effects on one's emotional status. Despite this, only a limited number of studies have examined the effect of litigation or compensation-seeking on patients' emotional state.

The MMPI-2 is a measure of personality and psychopathology that is commonly used in TBI samples. A study using this measure found that an mTBI litigating group reported elevations on the Schizophrenia and the Health Concern scales when compared to a non-litigating severe TBI group (Youngjohn et al., 1997). Examination of the validity scales from the MMPI-2 revealed no differences between groups, providing support for the claim that these elevated results for the mTBI litigating group were not due to intentional symptom exaggeration (Youngjohn et al., 1997). Berry et al. (1995) found that TBI patients seeking financial compensation had higher scores on a range of over-reporting scales as well as a lower score on an under-reporting scale on the MMPI-2 than head-injured patients who were not pursuing any financial compensation. Another study by Smith-Seemiller et al. (2003) found that patients involved in litigation scored higher on the Rivermead Post Concussion Questionnaire (which involves both cognitive and emotional issues) than those who were not in litigation.

The effects of litigation or compensation-seeking on emotional state have also been observed in non-TBI populations. Specifically, chronic pain patients seeking some type of financial incentive have been found to report elevated levels of somatic complaints and psychological problems, compared to chronic pain patients not seeking financial incentives (Gervais et al., 2000).

Conclusion

Litigation and compensation-seeking post mTBI has received relatively little attention in the literature, and hence it is difficult to draw firm conclusions in this area. This review goes some way to answering questions regarding the predictors of future litigation and compensation-seeking and the effects of this pursual on return to productivity outcomes.

The results of this review revealed that litigation was more commonly seen in mTBI patients as compared to moderate or severe TBI's, for reasons that are not fully understood. Patients who suffer more pain post-injury were more likely to pursue compensation or enter into litigation. Litigating patients demonstrate a different cognitive profile to their non-litigating counterparts, with studies indicating a decline in almost all cognitive domains, and a lack of expected improvement over time. While litigating patients have been found to perform more poorly on validity testing, this does not explain all the variance in cognitive performance. Litigation and compensation-seeking has also been reported to impact upon patients' emotional state as well as their subjective evaluation of functioning.

What is clear from this review is that litigation and compensation-seeking is a multifaceted area, which affects many aspects of a person's life. Considering how many mTBI patients go on to seek compensation or enter into litigation, this is an important area to understand for both clinicians and researchers. More studies are needed to replicate and strengthen previously reported results. In addition, in-depth studies which can answer questions such as why litigating and compensation-seeking patients take longer to return to work; why mTBI patients are more likely to seek compensation or enter litigation; and whether there are confounding factors which can explain the different cognitive profiles or litigating and non-litigating patients would enhance our understanding of this complex area.

Chapter 3: Occupation and mTBI

Why Study Occupation?

Importance of employment for the non-injured population.

Employment is often viewed as a central part of an individual's personal identity and sense of self (Jahoda, 1982; Paul & Batinic, 2010). It provides individuals with specific goals and ambitions and allows them to participate in productive activity as well as providing them with the opportunity to develop social relationships with others and improve upon valuable social skills. Jahoda (1982) developed the latent deprivation model which states that employment not only provides the manifest function of financial earnings, but it also provides an individual with five 'latent' or unintended functions. These latent functions are time structure, collective purpose, social contact, status, and activity. Time structure involves the opportunity to have organised time filled with planned activities (Jahoda, 1982; Paul & Batinic, 2010). Collective purpose involves the feeling of being useful and needed by others (Jahoda, 1982; Paul & Batinic, 2010). Social contact specifically relates to contact with others who are outside an individual's family circle which provides the individual with the opportunity to gain more information and to obtain the opinions of others (Jahoda, 1982; Paul & Batinic, 2010). Social status is provided by the work an individual does and is shaped by how others in the workplace view that individual (Jahoda, 1982; Paul & Batinic, 2010). Finally, activity involves being active in one's day-to-day functioning, whether this is a voluntary choice or one determined by external factors such as the need to earn an income (Jahoda, 1982; Paul & Batinic, 2010). These five latent functions are argued to correspond to basic human needs and are claimed to improve an individual's psychological well-being. This theory was examined in a study by Paul and Batinic (2010) who found support for four of the five latent functions of employment. Specifically, employment resulted in a higher level of time structure, social contact, collective purpose and activity. No differences in status were seen between employed and unemployed individuals.

There are also psychological benefits to employment, with employed individuals often having higher self-esteem, improved mood, better overall psychological and physical well-being, and a greater sense of control over their lives than their unemployed peers (Hoare & Machin, 2010; Kinicki, Prussia & McKee-Ryan, 2000; Mckee-Ryan, Song, Wanberg & Kinicki, 2005; Murphy & Athanasou, 1999; Winefield & Tiggemann, 1990). The World Health Organisation (WHO, 2005) reported that unemployed individuals were more likely to experience reduced social support, insecurity, hopelessness, greater risks for physical health and higher mortality, and increased rates of mental health problems than employed individuals. The Australian National Survey of Mental Health and Well-Being (Australian Bureau of Statistics, 2007) reported that 29% of 413,600 unemployed individuals had a mental health disorder which persisted for at least 12 months compared to only 20% of the 10.4 million employed individuals. This report also found that unemployed individuals were twice as likely to meet criteria for a substance use disorder and three times as likely to meet criteria for an affective disorder. Children of unemployed parents have also been found to be more likely to experience mental health disorders themselves (WHO, 2005).

Additional reasons to study employment after TBI.

There are a number of reasons why employment is an important outcome measure to examine following TBI. Firstly, it provides a useful and valid measure of recovery post-injury, and hence is one way for health care professionals to assess and monitor the impact of injury. It is common for the return to employment to be a graded process which is regularly reviewed by the individual themselves as well as by significant others who are involved in the rehabilitation program. The ability of an individual to return to their pre-injury employment generally requires them to have returned to a level that is close to their pre-morbid level of cognitive functioning. It is often not until individuals attempt to return to their pre-injury employment that they discover functional difficulties, which may have been subtle and hence not affected their daily functioning when they were not working. For example Wehman, Targett, West & Kregel (2005) noted that awareness of one's own strengths and weaknesses is most likely to develop when the individual is faced with real world experiences, such as employment. Hence, the ability to return to pre-injury employment and manage successfully is likely to signify to treating professionals that recovery of function is close to complete.

Secondly, the return to employment can signify the return to "normal" or pre-injury functioning for patients, which is a common goal post-TBI. Often individuals do not consider their recovery as complete until they have returned to work (Kolakowsky-Hayner & Kreutzer, 2001). Using both multidimensional (The Craig Handicap Assessment Capacity Technique, The Bigelow Quality of Life Questionnaire, and The Flanagan Scale of Needs) and global measures (The Global Quality of Life Measure), O'Neill et al. (1998) found that employment following TBI was significantly and positively associated with increased perceived quality of life, social integration and home and leisure activities. Importantly, employment contributed to the prediction of these areas over and above all other variables measured in the study (including age, gender, marital status, education, pre-injury income, injury severity and time since injury). Interestingly, the results suggested that part-time employment may be more beneficial to quality of life, social integration and home activities than full-time employment, as part-time workers would have had more free time which may allow them to meet other important life needs as compared to full-time workers (O'Neill et al., 1998).

There are also a range of psychological benefits and improvements in quality of life for TBI patient who return to work. These include increased independence and self-esteem as well as gaining greater opportunities for community participation and social integration, increased autonomy, and a greater level of control over their own life (Abrams, Barker, Haffey & Nelson, 1993).

Cunningham, Wolbert and Brockmeier (2000) conducted a qualitative analysis on the perspectives of individuals with severe mental illness regarding employment. While the sample did not involve TBI patients, a number of findings can be generalised to the TBI population. Participants who were successful in gaining and maintaining employment tended to view their work as a necessary part of their lives which allowed them more control and a higher level of self-regard, as compared to those who were unable to gain or maintain employment. Work was also seen as an important part of one's recovery for those who were able to maintain employment.

Return to employment post-TBI has been found to enhance recovery. A recent literature review by Wehman et al. (2005) found support for a range of ways in which being employed post-TBI can aid recovery. Specifically the authors found that employment provides the individual with motivation to get up in the morning; the opportunity to increase one's social network through developing new friendships; the opportunity to enhance self-esteem and perceived status; the increased likelihood of reducing physical disability and substance abuse; as well as providing the individual with an income resulting in more financial security and independence (Wehman et al., 2005).

It is also important to examine return to employment post-TBI in relation to caregivers, as the return to employment is likely to result in significantly less burden of care. TBI patients are typically young individuals who are in the early stages of their productive careers and employed years. When these individuals are unable to work (even if only temporarily) the burden of care often falls on spouses or caregivers, who then become responsible for financially supporting the unemployed individual. Caregivers have been found to experience significant stress and distress when placed in a position where they are required to care for a patient post-TBI, and importantly even less-severe TBI's have been found to result in significant carer distress (Ergh, Rapport, Coleman & Hanks, 2002). When a patient returns to work, caregivers have been found to demonstrate more independence and self-esteem, increased autonomy, more opportunities for community participation and social integration, and a greater level of control over their own lives (Abrams et al., 1993).

What is Required for Successful Employment?

There are a number of skills which are considered necessary for successful employment. These will always include both general factors which are valued by all employers as well as job-specific skills related to the particular role itself. Job-specific skills relate to training, knowledge and/or experience that are specific to a particular field of work, and hence will differ from job to job. Therefore the following discussion focuses on the more general factors which are viewed to be important and generalizable to most roles. The Employability Skills Profile (McLaughlin, 1995) is a list of personality traits that employers commonly seek in their employees. It was devised through a process involving a literature search along with discussions and reviews with employers and human resource professionals from a range of employment environments. While this list is in no way exhaustive it provides one of the few published criteria of personal attributes valued by employers. There are also many skills listed which may not be highly valued in some workplaces or professions. Table 1 provides a summary of the Employability Skills Profile.

Table 1: Summary of the Employability Skills Profile (McLaughlin, 1995)

Skill Area	Skills Valued
Communication	Understand/speak language Listen, understand and learn Read, comprehend and use written materials Written communication skills
Thinking	Think critically and act logically Understand and solve problems. Make use of results Effective use of technology, instruments and tools Apply specialised knowledge from various fields
Learning	Continue to learn and develop
Attitudes/Behaviour	Self-esteem and confidence Honesty, integrity and personal ethics Positive attitude towards learning and personal growth Initiative, energy and persistence
Responsibility	Ability to set goals and prioritise Ability to plan and manage time and other resources Accountable for one's own actions
Adaptability	A positive attitude towards change Respect for differences in diversity and individual differences Creativity – ability to think of new solutions
Teamwork	Ability to work with others Ability to work within an organisations specific culture Respect for the thoughts and opinions of others Demonstrate "give and take" in group tasks Seek a team approach where necessary Lead a group when appropriate

Clearly, there are a large number of general skills in a range of different areas which are needed for successful employment, or at least which make an individual more likely to succeed in the workplace. Many of the skills listed by McLaughlin (1995) are high-level skills which may be impaired or reduced following mTBI. Skills such as time management, creative or flexible thinking, and the ability to prioritise, are all considered higher-level executive functions which are commonly reduced following TBI (Belanger et al., 2005; Zakzanis et al., 1999). Hence it is understandable why individuals may not become aware of their difficulties until they attempt to return to work. It is possible that a mild TBI could impact upon one's ability to manage at work as effectively and efficiently as was the case prior to injury, particularly within the first three months post-injury.

Chapter 4: Return to Work Following Mild TBI: A Systematic Review

Introduction

An estimated 1.7 million individuals sustain a TBI in the United States every year, of which there are 1,365 Emergency Department visits, 275,000 hospitalisations and 52,000 deaths (Faul, Xu, Wald & Coronado, 2010). MTBI comprises between 70% - 90% of all TBI's (Boake et al., 2004; Cassidy et al., 2004; Drake, Gray, Yoder, Pramuka & Llewellyn, 2000; Ruffolo, Friedland, Dawson, Colantonio & Lindsay, 1999). Cassidy et al. (2004) reported the incidence of hospital-treated mTBI to be 100 - 300/100,000; however two national household surveys from the US report general or population rates to be closer to 600/100,000, suggesting that hospital-based figures underestimate the incidence of such trauma due to the large number of mTBI sufferers who do not seek medical treatment (Fife, 1987; Sosin, Sniezek & Thurman, 1996);. In the 2004 - 2005 period within Australia there were 22,710 hospitalisations due to TBI, with 60% being classified as a concussion or involving less than 30 minutes LOC (Helps, Henley & Harrison, 2008).

Statistics from the US Centre for Disease Control (CDC) estimate lost productivity associated with hospitalised mTBI in 1995 to be US$16.5 billion, which was just under half the total head injury-related costs that year (Boake et al., 2005). Johnstone, Mount and Schopp (2003) estimated US$642 million in lost wages, US$96 million in lost income taxes, and US$353 million in increased public assistance due to TBI in one year. Borg et al. (2004) found that direct (i.e., hospital-related) and indirect (i.e., economic) costs of TBI ranged from US$2.4-12.5 billion, with the indirect costs accounting for 92% of this figure. While specific data for mTBI was not reported, the authors acknowledge that as mTBI accounts for such a large proportion of all TBI's it is likely that the economic impact of mTBI is substantial. The Australian Bureau of Statistics

(ABS) reported a labour force participation rate of only 38.9% in individuals of working age following either TBI or stroke which equated to over 117,000 non-working individuals (ABS, 1993). Estimates of lost income due to TBI in Australia have been reported as AU$709.2 million for moderate to severe TBI (Access Economics, 2009). Unfortunately no data were reported for the mTBI population.

The high prevalence and cost of mTBI render it imperative that the factors contributing to a failure to return to productivity be determined. Between 7% and 84% of mTBI patients have been reported to experience ongoing symptoms (Boake et al., 2005; Drake et al., 2000; Friedland & Dawson, 2001; Guerin, Kennepohl, Leveille, Dominique & McKerral, 2006; Ruffolo et al., 1999; Zumstein et al., 2011). Reasons for this large variability include different definitions of mTBI, and wide ranges in the acuity of the cases studied (Drake et al., 2000).

A number of literature reviews and meta-analyses have examined return to work following TBI, with the majority including individuals with TBI severities that range from mild to severe. The results from these studies have consistently found that pre-injury employment (Nightingale, Soo & Tate, 2007; Willemse-van Son, Ribbers, Verhagen & Stam, 2007), executive functioning skills (Crepeau & Scherzer, 1993; Nightingale et al., 2007; Ownsworth & McKenna, 2004) and functional status/disability post-injury (Crepeau & Scherzer, 1993; Nightingale et al., 2007; Ownsworth & McKenna, 2004) are associated with a greater likelihood of return to productivity. In all but one study (Crepeau & Scherzer, 1993) sex has been found to have no relationship with return to productivity (Nightingale et al., 2007; Ownsworth & McKenna, 2004; Willemse-van Son et al., 2007). Examination of age, PTA duration, GCS score, LOC duration, length of hospital stay, and litigation/compensation-seeking status have all revealed inconsistent results regarding their prognostic value with return to productivity. Inconsistent results may be due to differences in sample characteristics (Crepeau & Scherzer, 1993; Van Velzen et al., 2009), methods of measuring variables (Nightingale et al., 2007; Ownsworth & McKenna, 2004; van Velzen et al., 2009), and different follow-up periods (Sherer et al., 2002).

As yet there has been no critical review of the literature that has focused exclusively on predictors of return to productivity in an mTBI sample. Studies that examine return to productivity by comparing different TBI severity groups are unable to differentiate between mTBI individuals with a favourable versus a poor outcome. Boake, McCauley, Pedroza, Levin, Brown and Brundage (2005) focused on lost productive work time in a mild to moderate TBI group and reported the mTBI and trauma control groups had similar durations of lost working time. The authors concluded that delay in return to work may be caused by factors associated with having experienced a general trauma rather than being specific to having sustained a TBI. Inclusion of a non-hospitalized mTBI group and an appropriate (i.e., general trauma) control group make this a particularly strong and well-designed study.

The purpose of the current study was to complete a systematic review of all the relevant literature pertaining to the assessment of return to productivity following mTBI in adults. During recent years the study of recovery of mTBI in contact sports has received increased attention, and it may be argued that this population provides the best mTBI model at the current time (Gardner, Shores & Batchelor, 2012; Gardner, Shores & Batchelor, 2010). While the results of these studies are of value in studying recovery and prognostic factors in recovery after mTBI, one of the crucial differences between athletes and the general population visiting the Emergency Department is the speed of recovery. Because of this inherent difference, the area of recovery in contact sports is not a focus of the current review. ”Specifically this review aims to examine the relationship between pre-injury (demographic and employment), injury-related (measures of severity), and post-injury (neuropsychological functioning, litigation/compensation-seeking status) variables and return to productivity following mTBI.

Method

Search strategy.

A comprehensive literature review was conducted through electronic searches of PsycINFO, Web of Knowledge, PubMed and Science Direct databases. A combined title search was conducted with the terms [head OR brain OR cerebral OR cranial] AND [injury OR damage OR trauma OR insult OR tbi OR mtbi OR concussion] AND [work OR vocation OR employment OR career OR job OR return OR psychosocial OR study OR home OR duties OR outcome OR prognostic OR prognosis]. No year limit was set, and articles from 1908 until April 2011 were retrieved. A total of 8260 articles were retrieved, of which 2237 were duplicates, leaving 6023 original articles to be reviewed.

The titles and abstracts of the 6023 articles were reviewed to determine if they met the following inclusion criteria. Where required information could not found in an abstract, the article was obtained and the methodology was examined:

1) The study examined an adult population (with all participants being 16 years or older).

2) The study reported an outcome of return to work/study/home duties, or a combination of these.

3) The study focused on mTBI, or in studies which involved different severity groups, specific results were presented for the mTBI group.

4) Severity of brain injury was defined by an objective severity measure (such as GCS score or PTA duration).

5) The study focused on TBI sustained in adulthood.

6) The study was not a case study.

7) The study was not an animal study.

8) A full-text version of the article was available.

9) The article was written in English.

10) The study focused on TBI only. In studies which included other causes of brain injury (such as cerebrovascular accidents, infections etc), specific results were reported for the TBI group separately.

11). Systematic reviews and meta analyses were included. Narrative reviews were excluded; however the reference lists were examined to ensure all relevant literature was included.

From the 6023 original articles, 5951 were excluded based on the above criteria. Figure 1 specifies the number of articles excluded for each of the above criteria. A total of 72 articles remained eligible for review. Reference lists of the 72 articles were examined for any other relevant articles, and 7 additional articles were derived, resulting in a total of 79 articles which were then reviewed in detail. Of these 35 studies were selected as the focus of the current review as they made specific predictions about return to productivity for an mTBI group. The process of article selection is depicted in Figure 1.

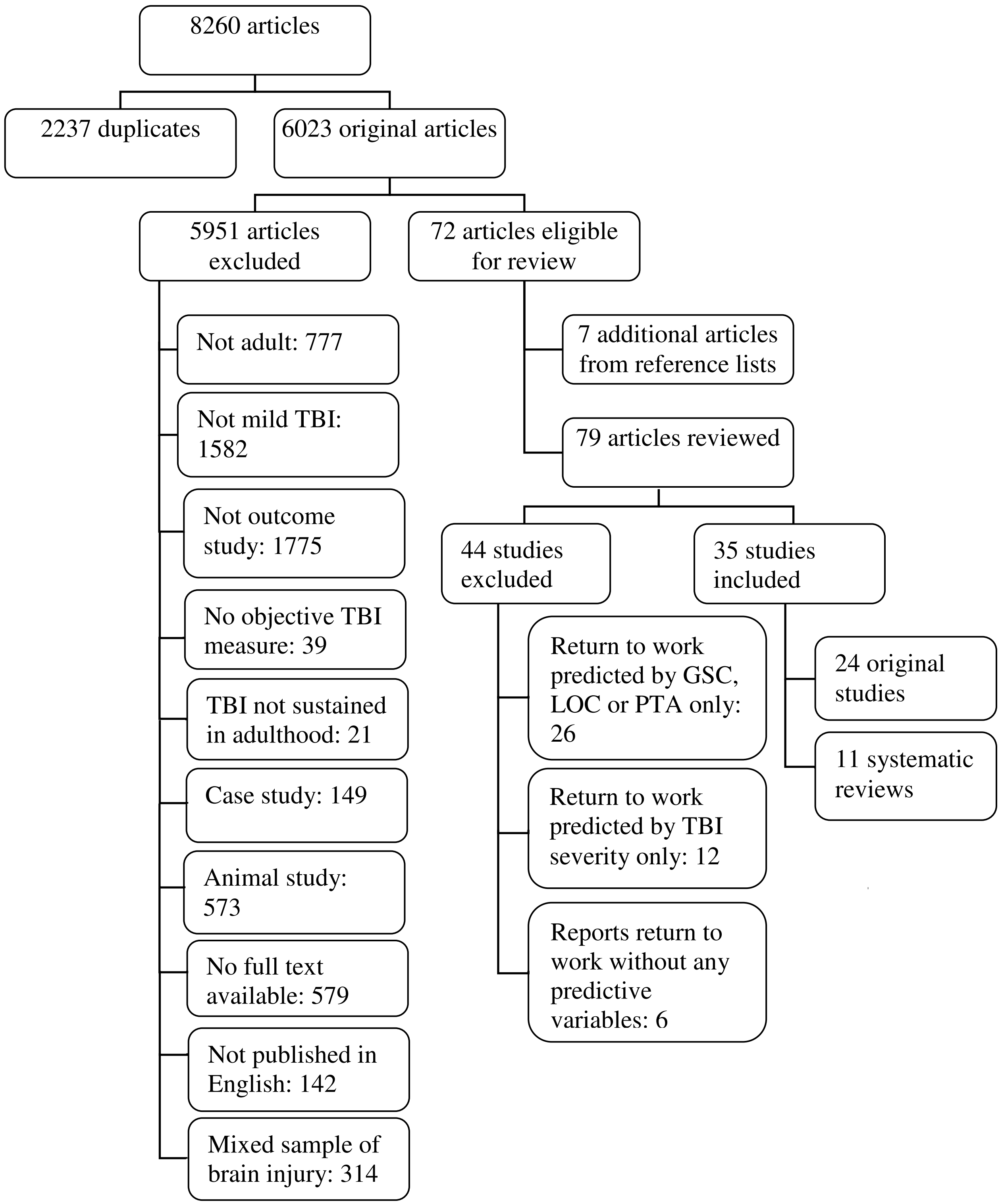


Figure 1: Schematic Representation of the Process of Article Selection for Inclusion in Review

The methodological quality of the included articles was scored based on a critical appraisal tool (adapted from Ownsworth & McKenna, 2004 and Pengel, Herbert, Maher & Refshauge, 2003). The appraisal tool involved eight items (detailed below), with each item scored as 0 or 1, apart from item one which was scored as either 0, 1 or 2. For item one, a score of 2 was assigned to studies which involved an initial assessment within one month of injury and a follow-up period of at least 12 months. A score of one was assigned to studies which involved an initial assessment within one month of injury and a follow up period of at least 6 months. A score of zero was assigned to studies with initial assessments more than one month post-injury or follow-up periods of less than 6 months. This resulted in possible total scores ranging from 0 - 9. Studies which scored 7 - 9 were classified as "commendable", studies scored as 5 - 6 were classified as "acceptable", studies scored as 4 were classified as "marginal" and studies scored as 3 or less were classified as "flawed" (Ownsworth & McKenna, 2004). "Flawed" studies were excluded from further analysis (Ownsworth & McKenna, 2004).

1) The study was either a prospective study or a well designed longitudinal study: Prospective studies were rated according to whether a) predictor variables were measured within one month post-injury and b) employment outcome was measured up to at least 12 months post-trauma.

2) The characteristics of the study sample and the selection criteria were clearly stated, including referral source, inclusion/exclusion criteria, age, education or pre-injury work status, time from injury to follow-up assessment and injury severity. Data was collected from the most objective and reliable source where possible.

3) Participants who were lost to follow-up or refused to participate were described. Included participants were compared to those lost to follow-up and/or those who refused to participate on relevant measures (e.g. age, gender, occupational status, injury mechanism).

4) The study employed a representative sample of participants. It involved either a multi-centre study or a single unit study involving consecutive admissions.

5) All variables were assessed using standardized measures for which normative data was available where possible. In cases where subjective information was collected data was collected from the most objective and reliable source.

6) Blinding of assessor: Information regarding employment outcome was collected independently of knowledge regarding performance on the predictor variables.

7) The study included an appropriately matched control group, such as an orthopaedic injury group.

8) The study used statistical methods appropriate for a prognostic study, including accounting for covariates.

Results

Of the 24 included studies, seven were either prospective studies or well-designed longitudinal studies including both early (within one month) predictor variables and late (at least 12 month) productivity outcome, while six included early predictor variables but only a shorter (i.e. 6 month) follow up period. The remaining 12 studies involved an initial assessment that was more than one month post-TBI or included a follow-up period of less than six months. The selection criteria and characteristics of the study sample were described in 18 studies. Eleven studies described participants that were lost to follow-up or refused to participate, and reported on any differences between them and the included sample. Twenty-four studies employed a representative sample involving either a multi-centre approach or a single unit approach involving consecutive admissions. Standardised measures of variables or the most objective measure when standardised instruments were not available was utilised in 23 studies. Only three studies involved blinded investigators. An appropriately matched control group was included in five studies. Statistical methods appropriate for a prognostic study were utilised in 17 studies. Four studies were rated as “commendable”; eight as “acceptable”, eight as “marginal”, and four as “flawed”. Table 2 presents the methodological scores for each study.

Table 2: Scores for each study regarding methodological quality

	Criteria								
Study	1	2	3	4	5	6	7	8	Total
Friedland (2001)	1	1	1	1	1	1	1	1	8
Dawson (2004)	2	1	1	1	1	0	0	1	7
Doctor (2005)	2	1	1	1	1	0	0	1	7
Ruffolo (1999)	1	1	1	1	1	1	1	0	7
Reynolds (2003)	2	1	1	1	1	0	0	0	6
Stulemeijer (2008)	1	1	1	1	1	0	0	1	6
Bazarian (2010)	0	0	1	1	1	1	0	1	5
Benedictus (2010)	2	0	0	1	1	0	0	1	5
Hanlon (1999)	2	1	0	1	1	0	0	1	5
Nolin (2006)	2	0	0	1	1	0	0	1	5
Stulemeijer (2006)	1	0	1	1	1	0	1	0	5
Vanderploeg (2003)	0	1	0	1	1	0	1	1	5
Drake (2000)	0	1	0	1	1	0	0	1	4
Guerin (2006)	0	1	0	1	1	0	0	1	4
McCullagh (2001)	1	1	0	1	1	0	0	0	4
Paniak (1998)	0	1	1	1	1	0	0	0	4
Paniak (2000)	0	1	0	1	1	0	0	1	4
Rimel (1981)	0	1	1	1	1	0	0	0	4
Stranjalis et al. (2004)	0	1	0	1	1	0	0	1	4
Van der Naalt (1999)	2	0	0	0	1	0	0	1	4
Erez (2009)	0	1	0	1	1	0	0	0	3
Pietrzak (2009)	0	1	0	1	0	0	0	1	3
Zumstein (2010)	0	0	0	1	1	0	0	1	3
Hsiang (1998)	0	0	0	1	0	0	0	0	1

Note. Scoring system adapted from Pengel, Herbert, Maher and Refshauge, (2003) and Ownsworth and McKenna (2004).

Table 3: Variables studied and results of individual studies rated as either "commendable" or "acceptable" (n = 12)

Study	Sample	Predictor Variables			Outcome Variable	Results
		Pre-injury	Peri-injury	Post-injury		
Commendable						
Friedland (2001)	64 mTBI, 35 Trauma controls	Occupation			RTW: 6-9 months (full return; modified return; no return)	1. Group Comparison (ANOVA) RTW: mTBI = trauma controls 2.Chi-square analysis: Occupation (higher RTW rate for jobs with greater independence/decision-making latitude, mTBI group only)
Ruffolo (1999)	50 mTBI	Age Sex Marital status Education Occupation	GCS LOC ISS	PASAT Reaction time Subjective problems checklist Sickness Impact Profile Social Interaction Discharge disposition	RTW: 6-9 months (premorbid level; modified level; no return)	1. Group comparison (Mann-Whitney *U* test; Chi-square analysis) -social interaction -discharge disposition -occupation (higher RTW rate for jobs with greater independence/decision-making latitude)

Doctor (2005)	418 TBI (mild-severe)		CT scan results		RTW: 1 year (relative risk of unemployment)	1. Relative risk of unemployment compared to population - CT scan results
Dawson (2004)	94 TBI (baseline); 68 (1 year); 47 (4 year) 15 family /friend controls	Age	ISS	24hr recall of 3 words	RTW or school: 1 and 4 years (return no difficulty; return with difficulty, no return)	1. Group Comparison (chi-square analysis) RTW: mTBI > moderate/severe TBI 2. Correlational - Age (1yr post) - ISS (1 yr post) - Recall over 24 hrs (4yrs post)
Acceptable						
Reynolds (2003)	97 mTBI	None	None	Compensation-seeking (non-seekers, admin seekers, legal seekers, dual seekers)	RTW: 3 and 12 months (days to return to pre-injury level)	1. Group comparison (Mann-Whitney *U* test) - admin vs non-seekers - legal vs non-seekers
Stulemeijer (2008)	280 mTBI (baseline) 201 (6 months)	Age Sex Education Emotional problems Physical /medical problems	GCS LOC PTA CT scan results Early symptoms Extracranial	PCS Post traumatic stress Fatigue Pain Self-efficacy	RTW: 6 months (return to premorbid level; reduced level/not working)	1. Univariate association with RTW: - Education -CT scan -Injury mechanism -Nausea/omitting in ED -Extracranial injuries -PCS

		Prior HI	injuries			-Pain -Fatigue 2. Logistic regression with backward selection -Education - Nausea/vomiting in ED - Extracranial injuries - Pain
Vanderploeg (2003)	Community dwelling Male army veterans 626 MHI 3896 no HI	Age Education Race IQ Area of Residence Medical problems Psychiatric difficulties	LOC Self-report of head injury	None	RTW: 8 years (FT vs not FT)	1. Logistic regression - IQ - Internalising difficulties - Race x residence area - Education x LOC - Race x residence area x LOC
Hanlon (1999)	100 mTBI Concussion clinic referrals	Age Sex Psychiatric history Prior concussion	Injury mechanism Injury type CT scan results	Depression Litigation Trails A Digit Span Logical memory Visual reproduction California Verbal learning Test Boston Naming	RTW: 1 year (poor; modified; good).	1. Group comparison (ANOVA) -Injury mechanism -Injury type 2. Correlations with RTW -Age -Neuropsych (WMS-R Logical Memory I, WMS-R Visual Reproduction II, Judgement of Line

				Test COWAT Judgment of Line orientation WCST Trails B Finger tapping test Grooved Pegboard		Orientation, Trails B) - Depression 2. Logistic regression (hierarchical and stepwise) Predict good outcome: - WMS-R Logical Memory I -WMS-R Visual Reproduction II Predict poor outcome: -injury mechanism (OSH) -injury type (fall, struck by object)
Bazarian (2010)	1425 mTBI Admitted to ED	Age Sex Income Race/Ethnicity Pre-injury pain medication use Prior TBI	GCS Injury Mechanism Extracranial injuries LOC CT scan results Analgesics in ED	None	RTW: three months (number of missed days)	1. Multinomial logit model -Income -Injury Mechanism Extracranial injuries Analgesics given in ED
Benedictus (2010)	434 TBI (mild-severe)	None	None	Differentiated Outcome Scale (physical, cognitive, behavioural and	RTW: 6 month (premorbid level; reduced level/not working)	1. Logistic regression -cognitive domain - behavioural domain

				social domains)		
Stulemeijer (2006)	299 mTBI 261 Trauma controls Consecutive ED admissions	None	Extracranial injuries (ISS)	None	RTW: 6 months (premorbid level; modified level/no return)	1. Group comparison (ANOVA) - Extracranial injuries
Nolin (2006)	85 mTBI	Age Sex	GCS PTA Retrograde amnesia Symptoms at ED	Subjective complaints at f/u PASAT Stroop Test CVLT	RTW 12-36 months (RTW; no RTW)	1.Group comparison (t-tests) -subjective complaints at f/u -CVLT words recalled -CVLT recognition 2. Logistic regression -Subjective complaints at f/u

Note. MVA = motor vehicle accident; RTW - return to work; FT – full time; MHI – mild head injury; HI – head injury; GCS - Glasgow Coma Scale; LOC - Loss of Consciousness; PTA - Post-traumatic Amnesia; ISS - Injury Severity Scale; PCS - Post Concussion Symptoms; ED – Emergency Department; ANOVA – Analysis of Variance; PASAT - Paced Auditory Serial Attention Test; COWAT - Controlled Oral Word Association Test; WCST – Wisconsin Card Sorting test; WMS-R – Wechsler Memory Scale Revised; f/u – follow up.

Table 4: Variables studied and results of individual studies rated as "marginal" (n = 8)

Study	Sample	Predictor Variables Examined			Outcome Variable	Results
		Pre-injury	Peri-injury	Post-injury		
Van der Naalt (1999)	67 TBI (mild-mod) GCS 9-14	Variables examined for mTBI patients not specified	PTA	Variables examined for mTBI patients not specified	RTW: 1 year post (premorbid level; premorbid level modified; different work, lower level; no return)	Group comparison - PTA (24 hours or less; >24 hours) for GCS 14 group
Paniak (1998)	111 mTBI Hospital ED	None	None	Treatment group (single session (SS), or treatment-as-needed (TAN))	RTW: 3-4 months (days to return to pre-injury level)	1. Group comparison (t test) NS: SS and TAN
Stranjalis (2004)	100 mTBI Consecutive ED admissions	Age Sex Occupation	Serum S-100B Injury mechanism Neurological symptoms LOC PTA	None	RTW: 1 week, 4 weeks (RTW; no RTW)	1. Correlation -S-100B 2. Logistic regression -S-100B

McCullagh (2001)	57 mTB Consecutive TBI clinic admissions	None	GCS (13-14 vs 15) CT scan results PTA (<1hr vs 1-24 hrs)	None	RTW: 5-6 months (return to premorbid level; not returned to premorbid level)	1. Group comparison (chi-square analysis) -NS
Guerin (2006)	110 mTBI (referred) Poor recovery at 1 month	Age Sex Education Neurological diagnoses (prior TBI; other) Chronic health problems Psychiatric diagnoses Insurance	GCS Direct head impact (y/n) CT scan findings Associated injuries Pain Subjective symptoms at admission	Anxiety/ depression Time between TBI and intervention	RTW (y/n) Time post-TBI not mentioned (follow-up at “completion of intervention”	1. Logistic regression -Age -Subjective symptoms at admission -Insurance policy
Drake (2000)	121 mTBI Active military personnel	Age Education Army Rank Verbal IQ	LOC PTA GCS	CVLT - total CVLT – cued recall COWAT WCST – categories Map planning Mazes test PASAT FLoPS	RTW: three months post study enrolment (mean 175 days post-TBI) (premorbid level; reduced level)	1. Group comparison (F test) - Age -Rank -CVLT total -CVLT cued recall -Verbal fluency -Map planning -FLoPS -NBRS

				NBRS		2. Stepwise DFA -Age -CVLT delayed free recall -COWAT -Map planning
Rimel (1981)	424 mTBI Consecutive medical centre admissions	Age Sex Education Occupation Income SES Health/ disability insurance Previous head trauma	LOC GCS Extracranial injuries	None	RTW: three months	1. Group comparison (*t* test, chi-square analysis) - Age -Education -Employment -Income -SES
Paniak (2000)	118 mTBI Consecutive ED admissions	Age Sex Psychological treatment SES Alcohol use No. adverse life events No. previous mTBI's	Medications prescribed PTA ISS	Compensation status	RTW: 3-4 months	1. Stepwise DFA analysis -Compensation-status -Age

Note. RTW - Return to Work; PTA - Post-traumatic Amnesia; GCS - Glasgow Coma Scale; LOC - Loss of Consciousness; ISS - Injury Severity Scale; ACRM - American Congress of Rehabilitation Medicine; NS – Non significant; CAVLT - California Auditory Verbal Learning Test; COWAT - Controlled Oral Word Association Test; WCST - Wisconsin Card Sorting Test; PASAT - Paced Auditory Serial Attention Test; FLoPS - Frontal Lobe Personality Survey; NBRS - Neurobehavioural Rating Scale; DFA - Discriminate Function Analysis.

As studies from both the “commendable/acceptable” and “marginal” categories examined similar variables, the results of all studies are reported together. However, results from studies with higher ratings are afforded more strength than those with lower ratings. For specification of how the calculated quality index was weighted please refer to the detailed information provided on page 51-52. Tables depicting the level of support for each of the pre-injury, peri-injury and post-injury variables can be found in Appendix A.

Pre-injury variables.

Age was examined in 11 studies with the relationship between age and return to productivity being positively associated in two studies, negatively associated in four studies, and non-significant in five studies. The two studies which reported older individuals to be more likely to return to productivity were rated as “marginal” and have limited generalisability due to the population studied. Specifically, Drake et al. (2000) examined active duty military personnel, who required medical clearance to return to work, while Rimel et al. (1981) focused on a civilian group, a high proportion of whom were not in paid employment, and who were instructed to return to their pre-morbid activities “as soon as possible”. Sex was examined in nine studies, all of which found no significant association with return to productivity, providing strong and consistent evidence of a lack of association.

Education was examined in six studies, with two finding a positive association, with higher levels of education being associated with a higher likelihood of returning to productivity, while four found no association. Rimel et al. (1981) reported a positive relationship in a group with a relatively low level of education (mean 9.6 years, compared to other groups which tend to have a mean of 12-13 years education). This relationship may be further examined in future research.

Occupation has been discussed in four studies with a positive relationship with return to productivity reported in three studies. The method of categorizing occupations may have had some bearing on the results. When occupations were divided into those with more or less decision-making capacity/independence, individuals in jobs with more decision-making and independence were more likely to return to work (Friedland & Dawson, 2001; Ruffolo et al., 1999). Ruffolo et al. (1999) suggests that those in higher-level jobs tend to have more education, longer tenure and better coping strategies and support, all of which assist their return to work. Boake et al. (2005) also discuss this issue and suggest that higher-status roles allow for greater flexibility. However it has also been suggested that it can be more difficult to return to highly skilled roles due to the role demands which often require simultaneous processing of information, organisational skills and memory (Ruffolo et al., 1999). Stranjalis et al. (2004) categorized occupation differently, separating participants into self-employed, salaried, student, home duties/retired, and unemployed and found no association between occupation and return to productivity. The current results suggest support for those in higher-status roles returning to work sooner.

While infrequently studied, individuals with higher incomes have been found to return to work sooner than those earning lower wages (Bazarian, Blyth, Mookerjee, He & McDermott, 2010; Rimel et al., 1981). It is possible that the relationship between income and return to productivity is mediated by occupation. Rimel et al. (1981) examined occupation and income, and found those in higher skilled positions to be more likely to return to work, however no data was reported on the correlation between income and occupation.

Peri-injury variables.

LOC was examined in eight studies all of which reported no significant association with return to productivity. The relationship between GCS and return to productivity in mTBI has been examined by studies comparing individuals with GCS scores of 13, 14 and 15. All of the eight studies which examined this variable reported a non-significant result. Duration of PTA and return to productivity was examined in five studies, four of which were rated as “marginal”. Only one study reported that longer PTA durations were associated with poorer return to productivity while the remaining four reported no significant association. In the marginally rated study which reported a significant negative relationship van der Naalt, van Zomeren, Sluiter & Minderhoud (1999) included more severely injured patients in their “mTBI” group, who had a mean PTA duration of 5.5 days, which by conventional standards would constitute a “severe” TBI (Teasdale, 1995). These results suggest that PTA is unlikely to be an effective predictor of return to productivity within the mTBI group. The lack of a significant relationship for these injury measures is not surprising and may be reflective of a reduced range, or could reflect the homogeneity of the mTBI group.

The presence of extracranial injuries was examined in eight studies, with four reporting a negative relationship with return to productivity and four reporting no significant relationship. Most studies utilised the ISS score, with some treating it as a categorical variable, while others treated it as numerical. All of the studies which reported a significant relationship were of high quality. Methodological issues in those studies that did not find a significant association, included a small sample size (Dawson, Levine, Schwartz & Stuss, 2004), a low percentage of individuals with extracranial injuries (Rimel et al., 1981), and a non-representative sample, which consisted of referred patients who demonstrated a "disproportionate psychological reaction and/or slowed functional recovery" (Guerin et al., 2006).

The relationship between negative and positive brain CT scan results and return to productivity received mixed support. The presence of CT abnormalities following mTBI would classify a patient as having suffered a "complicated mTBI", and although such patients are typically considered to have a different recovery trajectory from uncomplicated mTBI (often being more similar to moderate TBI), they will be discussed briefly here. Three studies (one rated as "commendable" and two rated as "acceptable") reported no differences with regard to return to productivity for those with positive CT scan findings as compared to those with no CT abnormalities, whereas three studies (one rated as "acceptable" and two rated as "marginal") found that brain CT abnormalities predicted poor return to work. A number of methodological issues concerning those studies which failed to find a relationship warrant mentioning. Hanlon et al.'s (1999) results may be confounded by participants' medico-legal status, as 48% of those with negative CT findings reported some legal involvement compared to only 18% of those with CT abnormalities. It is possible that the high level of legal involvement in the CT negative group resulted in these individuals being less likely to return to productivity, hence resulting in no significant differences between the two groups. While the relationship between these two variables was not examined, the authors did note that there was no difference in return to productivity for those involved in litigation versus those not in litigation for the sample as a whole. Unfortunately no measures of effort were administered. Another study (Guerin et al., 2006) which failed to find an association between CT abnormalities and return to productivity involved a sample who demonstrated slowed functional recovery or a disproportionate psychological reaction after their injury, and hence would not be generalisable to the mTBI population as a whole. Therefore it is likely that the presence of CT abnormalities is associated with a reduced likelihood of returning to productivity.

Injury mechanism was examined in four studies, with three finding a link with return to productivity and one finding no association. Studies finding an association were all in the higher methodologically ranked category. Stulemeijer, van der Werf, Borm and Vos (2008) found a significant univariate association between injury mechanism and return to work; however this relationship did not remain significant in the multivariate model when education, the presence of nausea/vomiting, extracranial injuries and severe pain were included. Bazarian et al. (2010) found that motor vehicle accidents, motorcycle accidents and falls resulted in more days of work compared to other injury types (sports/cycling, pedestrians, and assaults), whereas Hanlon et al. (1999) found vocational outcome to be poorer in those injured by falls and falling objects compared to motor vehicle accidents. Hanlon et al. also divided injury mechanism into those where the head struck an object, the head did not strike an object, and an object struck the head, and found that vocational outcome was poorer in injuries where an object struck the head compared to those where the head struck an object. It is worth noting that Hanlon et al.'s patients injured by falls or falling objects were older than patients in other groups. They were also more often injured at work and required medical clearance to return, which may have extended their time off work. They were also more likely to be involved in litigation, and while litigation was not a significant predictor of return to work, it should still be considered when interpreting these findings. Time from injury to follow-up was extremely variable in this study, with assessments conducted anywhere from 3 - 40 months post-injury. While there is strong evidence that injury mechanism can impact upon return to productivity, more research is necessary to delineate the specific injury types that are associated with poor outcome and the underlying reason for this. Studies need to control for possible confounding factors such as litigation, which may be more prevalent following certain types of injuries.

The presence of any PCS symptoms during Emergency Department admission have been examined in relation to return to productivity in four studies, with two finding a significant association and two finding no link. All of these studies used different measures of what constituted the presence of symptoms. Furthermore, some studies used the number of symptoms endorsed while in others symptoms were dichotomised with participants rated as either having or not having any symptoms, making it difficult to make comparisons across studies (McCauley et al., 2001).

Post-injury variables.

There are a wide variety of post-injury variables which have been examined in the included studies, with little overlap of variables between studies. The variables most commonly examined were verbal memory (Dawson et al., 2004; Drake et al., 2000; Hanlon et al., 1999; Nolin & Heroux 2006), executive functioning (Drake et al., 2000; Hanlon et al., 1999; Nolin & Heroux 2006) and litigation status (Hanlon et al., 1999; Paniak et al., 2000; Reynolds et al., 2003). Verbal memory tests were examined in four studies, with all finding a significant association between stronger verbal memory skills and return to productivity. Despite there being a range of different verbal memory tests utilised in different studies, these results suggest strong support for the predictive power of verbal memory (Dawson et al., 2004; Drake et al., 2000; Hanlon et al., 1999; Nolin & Heroux 2006), and further studies utilising other verbal memory tests would be valuable.

Four studies examined executive functioning, with three finding that stronger skills predicted better productivity outcome, and one finding no association. The use of different tests makes direct comparison difficult. Tests which were found to be positively associated with return to productivity were the Trail Making Test B, a measure of divided attention; the Behavioural Assessment of the Dysexecutive Syndrome (BADS) Rule Shift Cards test, a measure of mental flexibility (Wilson, Alderman, Burgess, Emslie & Evans, 2003); BADS Zoo Map test, a measure of planning and rule-adherence (Wilson et al., 2003); BADS Modified Six Elements test, a measure of time management (Wilson et al., 2003); and the number of correct categories from the Wisconsin Card Sorting Test (WCST), a measure of mental flexibility. These results suggest that executive functioning is likely to be a good predictor of later return to work; however more research is needed to identify which specific executive functions are best predictive of return to work following mTBI.

Litigation/compensation-seeking status was examined in three studies, with two reporting that involvement in litigation or compensation-seeking following mTBI was associated with a reduced likelihood of returning to full productivity (Paniak et al., 2000; Reynolds et al., 2003). Reynolds et al. (2003) compared legal seekers, administrative seekers (such as those seeking sick leave, disability pensions etc.) and non-seekers. Their results consistently demonstrated that legal and administrative seekers took significantly more time off work than non-seekers. A particular strength of this study is that information was collected at the time of injury as well as at 3 and 12 months post-mTBI, allowing for the evaluation of change over time. Litigation/compensation-seeking significantly predicted time off work at all time points. Paniak et al. (2000) focused on mTBI patients who underwent a treatment program and found that those involved in litigation at 3 - 4 months post-mTBI were significantly less likely to have returned to work at that time. Hanlon et al. (1999) did not find a significant association between litigation/compensation seeking and productivity; however the authors do not specify how this variable was recorded and the relationship appears to have been examined in a post-hoc method to assess whether litigation was a confounding variable in the relationship between injury mechanism and return to productivity. The wide range of follow-up periods (ranging from 3-40 months post-mTBI) also makes it difficult to draw firm conclusions from this one study, particularly given that time post-injury can significantly impact outcome in a range of areas (Meares et al., 2011).

Overall, results from these studies suggest that involvement in litigation/compensation-seeking is likely to be a significant predictor of return to work prospects. This relationship may be due to a range of factors which could include exaggerated impairment (Binder, 1993; Green & Iverson, 2001; Green, Iverson & Allen, 1999; Stulemeijer et al., 2007); more severe injury (Paniak et al., 2002); or higher levels of pain (Paniak et al., 2000; Reynolds et al., 2003). Compensation-seekers have been found to use more prescription medications as compared to non-seekers (Reynolds et al., 2003). This could suggest higher levels of pain in this group. Paniak et al. (2000) also mention this possibility; however it has not yet been extensively examined. Poor return to productivity in litigious groups could also be associated with the higher likelihood of psychological issues (such as depression, anxiety or post-traumatic stress), post-concussion symptoms or stress associated with the litigation process (Miller, 2001; Mooney, Speed & Sheppard, 2005; Stulemeijer et al., 2007; Wood & Rutterford, 2006). Further investigation of the underlying reasons for this association may be a valuable focus for future research.

Discussion

The current study represents the first systematic review of return to productivity in mTBI. Specifically this review aimed to determine relevant pre-injury, injury-related, and post-injury variables that are able to predict return to productivity post-mTBI. The results of this review demonstrate that there are pre-injury, peri-injury and post-injury variables that all demonstrate strong predictive power in return to productivity post-mTBI. The mTBI patients who are most likely to experience a successful return to productivity are those who held higher status jobs pre-injury with higher pre-injury incomes, who have no extracranial injuries or any CT abnormalities, are not pursuing any litigation or seeking any compensation, and who demonstrate stronger verbal memory and executive functioning post-injury. It is also important to acknowledge the variables which have consistently been found to have no bearing on return to productivity, which include sex, GCS score, length of LOC and PTA duration.

There were some weaknesses in the studies included in this review which warrant mentioning, particularly considering they may limit the strength of the results reported. This review as a whole contained eight studies rated as marginal, eight rated as acceptable and only four rated as commendable. Study ratings were taken into account, especially when conflicting results were found; however the inclusion of a large proportion of marginal studies may have limited the strength of some conclusions drawn.

Within individual studies, the most common methodological weakness was the omission of assessor blinding, which may result in biased results. Lack of an appropriate control group was another common weakness. Less than half of the included studies compared participants to those who were lost to follow up or declined to participate, resulting in possible selection bias. Only 7 studies (out of 25) included both an acute (within one month) assessment of predictor variables and a follow-up of at least 12 months post-injury, making it difficult to make confident claims regarding early prediction of later productivity, which is a common goal in rehabilitation following TBI. Conclusions regarding which specific neuropsychological tests were predictive of return to productivity were limited by the variability of tests used in different studies and the minimal overlap between studies. Therefore only general neuropsychological domains could be commented on regarding their prognostic value.

While this review achieved the aim of determining which pre-injury, peri-injury and post-injury variables were predictive of later return to productivity, questions still remain regarding the underlying reason for associations found. For example, it remains unclear why individuals involved in litigation of compensation-seeking return to productivity later than non-litigious individuals.

Publication bias is an inherent weakness in all systematic reviews. As studies with significant findings are more likely to be published, it is reasonable to expect that studies with null results have been omitted. Therefore, the possibility of publication bias should be kept in mind when interpreting these findings, particularly as it is known to impact upon systematic review results (Moher, Liberati, Tetzlaff, Altman & The PRISMA Group, 2009).

Future research may wish to include study and home duties in the definition of "productivity". This would allow for a greater understanding of how an mTBI impacts upon an individual's overall functioning, particularly if they reduce their functioning in one area (for example home duties) in order to better manage in another (such as paid employment).

Chapter 5: Overview, Aims and Hypotheses of the Current Study

Aims of the Study

The principal aim of the current study was to examine factors predicting a successful return to pre-injury productivity status following mTBI. The study was designed to determine whether there were specific demographic, injury-related or neuropsychological variables that could accurately predict those individuals most likely to return to pre-injury productivity status by three months post mTBI.

Hypotheses

H1: Individuals who sustained an mTBI would be less likely to have returned to their pre-injury productivity levels by three months post-injury compared to trauma controls.

H2: Longer PTA duration would be associated with a reduced likelihood of a full return to productivity at three months post-injury for the mTBI group. The predictive value of PTA has received mixed support in the literature to date, and hence the current study aimed to further examine this area.

H3: Demographic variables of older age at the time of injury, fewer years of education and lower pre-morbid intellectual functioning would all be associated with a reduced likelihood of a full return to productivity at three months post-injury for both the mTBI and the trauma control groups. Age and education have received mixed support regarding their prognostic value in return to productivity, and hence warrant further investigation. Intellectual functioning has received very little attention and also deserves further investigation.

H4: Sex would not be associated with return to productivity for either the mTBI or the trauma control group.

H5: Injury variables of subjective report of pain, presence of headaches and longer length of hospital stay would all be associated with a reduced likelihood of a full return to productivity at three months post-injury for both the mTBI and trauma control groups. Pain and headaches were predicted to be associated with return to productivity because they have been found to impact upon individuals' lives, and are important to study in the mTBI population due to the fact that they are common post-injury issues. Length of stay was also examined as a marker of injury severity.

H6: Better performance on neuropsychological tests of verbal learning, information processing speed and reaction time, would be predictive of an increased likelihood of a full return to pre-injury productivity at three months post-injury for the mTBI group. There would be no association between performance on these neuropsychological tests and return to productivity for the trauma control group.

H7: MTBI and trauma control patients involved in either litigation or seeking compensation would be less likely to have returned to their pre-injury productive status by three months post-injury than individuals who were not involved in either litigation or compensation-seeking.

Chapter 6: Methods

The current study was part of a larger project investigating outcome following mTBI (see Meares et al., 2008). The larger study investigated psychological and cognitive outcomes following mTBI. Conceptualisation of the current study was largely the work of the candidate under the guidance of the Macquarie University primary and associate supervisors. The candidate was involved in data collection and was solely responsible for the analysis and interpretation of the results and compilation of the current thesis. Ethical approval for the study was obtained from both Macquarie University Ethics Committee and Westmead Hospital Ethics Committee.

Participants

Consecutive admissions to Westmead Hospital (a Level 1 trauma hospital) in Sydney, Australia between April 2004 and June 2006 were examined through a daily trauma list to determine if patients met the inclusion criteria (see below). Eligible patients were then approached by a researcher who explained the nature and purpose of the study. Informed written consent was obtained from all patients who elected to participate.

All participants in the study were required to have sustained either an mTBI or a traumatic non-brain physical injury (trauma controls). MTBI patients were classified according to the World Health Organization (WHO) Collaborating Task Force operation criteria for mTBI (Carroll, Cassidy, Holm, et al., 2004). Hence mTBI was defined as an acute brain injury caused as the result of mechanical energy to the head from external physical forces, resulting in:

1.) One or more of the following:
    a. Confusion or disorientation;
    b. Loss of consciousness (LOC) of 30 minutes or less;
    c. Post-traumatic amnesia (PTA) lasting less than 24 hours; and/or
    d. Other transient neurological abnormalities (such as focal signs, seizure); and
2.) Glasgow Coma Scale (GCS) score of 13 - 15 after 30 minutes post-injury or on presentation to hospital.

For the purposes of the current study individuals with an intracranial lesion not requiring surgery were excluded as they were considered to have sustained a mild complicated TBI (Kashluba et al., 2008; Williams et al., 1990; McCauley et al., 2001).

Inclusion and exclusion criteria.

In addition to the above criteria regarding mTBI classification, all participants were required to meet the following study inclusion criteria:

1) Aged between 18 and 65 years at the time of injury. This age range was selected for two reasons. Firstly, as the main outcome under investigation was return to productivity the minimum age for inclusion was set at 18 years as individuals under this age were unlikely to have been in paid employment prior to injury. The maximum age for inclusion was set at 65 years in order to exclude retired individuals. The maximum age of 65 also reduced the likelihood of participants

having age-related cognitive impairment, the incidence of which has been reported to significantly rise from the age of 65 years onwards (Unverzagt et al., 2001).

2) Not in PTA at the time of the initial assessment, indicating that participants did not meet criteria for a severe TBI and that they were able to complete the assessment adequately.
3) Admitted to hospital within 24 hours of the injury in order to ensure accurate measures of initial injury severity and to confirm diagnosis of mTBI (based on Carroll et al., diagnostic criteria).
4) Initial assessment completed within 14 days of injury to ensure that the assessment reflected the sub-acute phase, which is classified as approximately 5 - 30 days post-injury, and to allow for clear differentiation from the three month follow up data which focused on the chronic phase post-injury, which is characterised as more than 30 days post-injury (McCrea et al., 2009) .
5) Three month follow up assessment completed within 150 days of injury to ensure that all participants were assessed at a comparable time post-injury.
6) Adequate command of the English language in order to make sure participants had a full understanding of standardised test instructions.
7) IQ of 70 or greater as measured by the Wechsler Test of Adult Reading (The Psychological Corporation, 2001) to ensure that the results were not confounded by any effects of developmental or intellectual delay.
8) Medically fit to participate to ensure that no participants had serious physical injuries that would prevent them from complying with standardised administration of tests.

The exclusion criteria were as follows:

1) Evidence of any pre-existing cognitive impairment. Pre-existing cognitive impairment was determined by participants' report of any history of a cerebrovascular event, neurological disorder or severe TBI.
2) Evidence of poor effort as measured by the Word Memory Test (Green, Allen & Astner, 1996) which was administered at the three month assessment. The criteria employed to classify a performance as "poor effort" involved a score of 82.5% or below on immediate recall, delayed recall, or overall consistency score (Green et al., 1996).
3) Pregnant at the time of the initial assessment. Studies have provided inconsistent results regarding the effect of pregnancy on memory, with some studies finding no objective evidence of memory impairment in pregnant women (Casey, Huntsdale, Angus & Janes, 1999; McDowall & Moriarty, 2000), while others have reported significant effects (Buckwalter et al., 1998; de Groot, Hornstra, Roozendaal & Jolles, 2003; de Groot, Vuurman, Hornstra & Jolles, 2006). A recent meta-analysis by Henry and Rendell (2007) found evidence to support poorer performance on demanding memory tasks which also involved an executive component (i.e. those that involved effortful and organised self-initiated retrieval) in pregnant women. Although results are mixed as to the effects of pregnancy on memory functioning, it was thought necessary to exclude pregnant women to ensure that any possible effects of pregnancy on memory did not influence the current results.
4) Evidence of psychosis, active suicidality or physical injury that was due to self-harm. This criterion was adopted in order to exclude acute psychiatric co-morbidities.

5) Having suffered only a minor physical trauma. Individuals with minor trauma are likely to be different from those who have experienced a major trauma in terms of the psychological effects of the trauma, duration of hospital stay, and the effect of hospitalisation on performances (both psychological and cognitive). This could potentially add a selection bias, where differences in results could be due to differences between the mTBI and trauma control participants rather than due to the injury itself (Dikmen, Machamer & Temkin, 2001).
6) Unable to complete the full assessment at either the initial or the three month assessment.
7) Residing either interstate or overseas due to the likelihood of these patients not being available for the three month assessment.

Selection of the final sample.

A total of 4247 trauma admissions were screened, of which 342 met the inclusion criteria. Informed consent was obtained from 227 (66.4%) participants, with the remaining participants declining to participate. Figure 1 presents a flow chart of those who did and did not meet criteria for the current study.

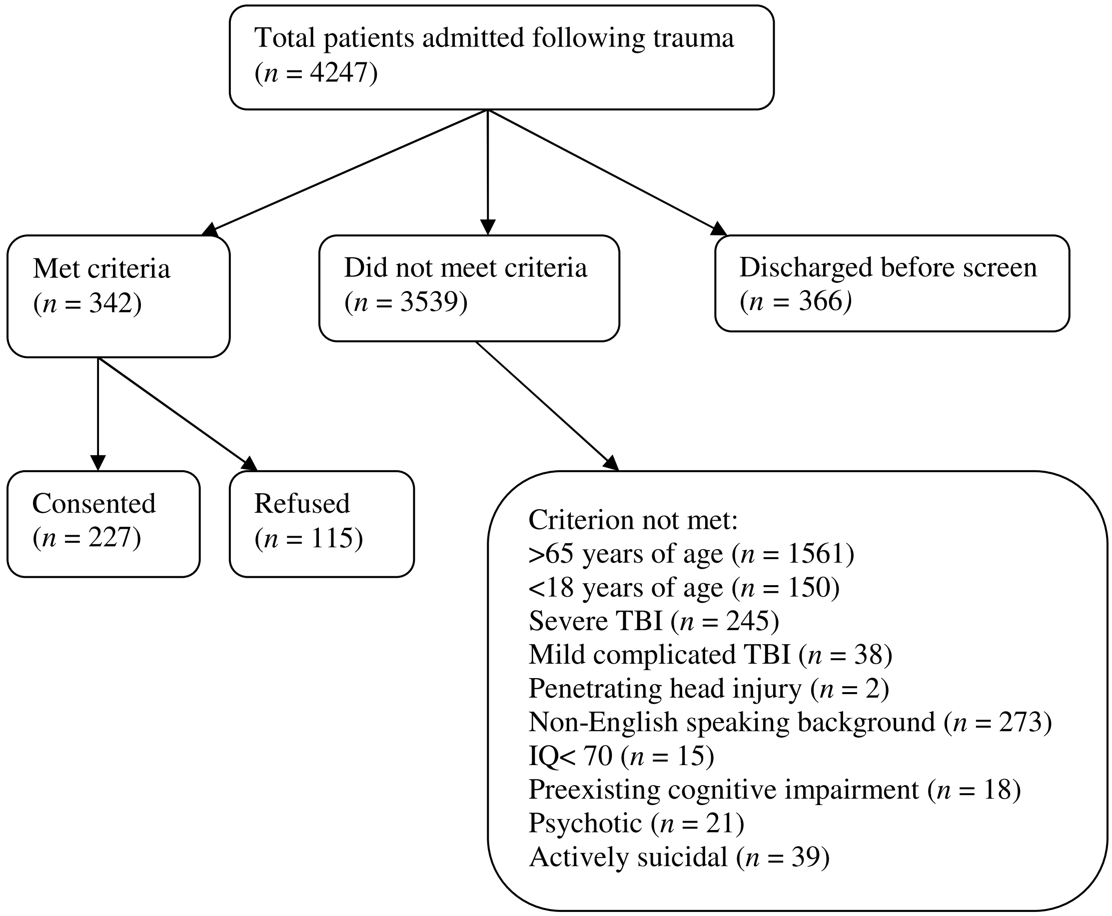


Figure 2: Flowchart depicting patients who did and did not meet criteria for current study.

Of the 227 participants who consented, a total of 209 (92.0%) completed the initial screen, while 18 (7.9%) were discharged prior to assessment. Before the three month assessment, 56 participants withdrew and a further 40 participants were excluded because they did not meet the inclusion criteria (see Figure 2). The final sample comprised 56 mTBI participants and 57 trauma controls. Figure 2 presents a flow chart of those excluded and shows the selection of the final sample.

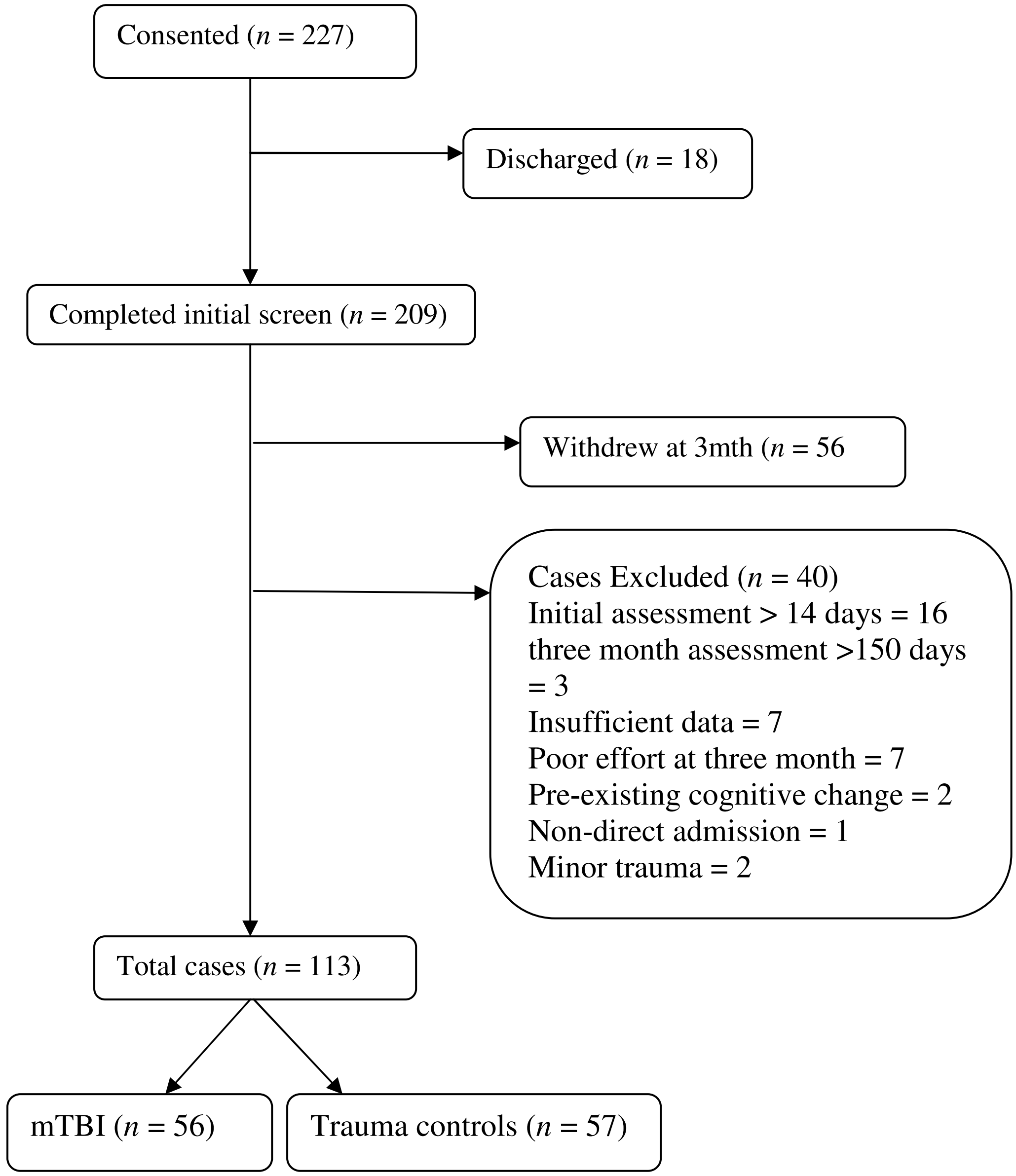


Figure 3: Flowchart depicting final participant sample.

All participants were screened within 14 days of injury, with the average time from injury to initial screening being 4.99 days (SD = 2.76 days; range 1 to 14 days). The three month assessment was carried out a mean of 106.85 days post-injury (SD = 14.94 days; range 82 to 148 days) and an average of 102.7 days after the initial assessment (SD = 14.22; range 76 to 147 days).

Individuals who refused to participate in the study did not differ from those who consented in terms of sex, age, injury severity, or days hospitalised (see Meares et al., 2008). Individuals who were discharged before the initial screen did not differ from those who consented in terms of sex χ^2 (1,209) = 2.65, p = .103, or age t(591) = 1.24, p = .215). There were, however significant differences in terms of injury severity score (Association for the Advancement of Automotive Medicine, 2001) t(591) = 3.44, p = .001 and length of hospital stay t(591) = 6.50, p = .001. Consistent with the inclusion criteria, individuals who were discharged before the initial screen had lower injury severity scores and shorter hospital stays (both as would be expected) compared to those who completed the initial screen (see Meares et al., 2008).

Individuals who were either excluded or withdrew from the study prior to the three month assessment did not differ from those who completed the assessments in terms of age t(207) = .588, p = .557; injury severity t(207) = .736, p = .753); sex χ^2(1,209) = .074, p = 0.786; occupational status (i.e. full time/part time etc.) χ^2(2,209) = 4.155, p = .125); or occupation χ^2(3,209) = 2.978, p = .395. Individuals who were either excluded or withdrew from the study had significantly longer hospital stays $t(207) = -3.156$, $p = 0.002$. Those who were excluded or withdrew from the study were in hospital for an average of 12.31 days, while those who completed the study were in hospital for an average of 7.32 days.

Demographic and injury-related information of the mTBI sample.

Participants who suffered an mTBI were predominately male (69.6%). The mTBI participants had a mean age of 36.29 years (SD = 14.40, range 18 to 64.11 years) at the time of injury, with an average of 11.64 years of education (SD = 2.94, range 6 to 23 years). The mean pre-morbid Full Scale IQ score (determined by a reading task and demographic variables) was 100.32 (SD = 10.49, range 70 to 122).

The majority of mTBI participants were injured in a motor vehicle accident ($n = 46$; 82.1%). Within this group, 32.1% were motor vehicle drivers, 25.0% were motor vehicle passengers, 14.3% were motorcyclists, 7.1% were pedestrians, 1.8% were bicyclists, and 1.8% were involved in motorboat accidents. Other mechanisms of injury were falls ($n = 6$; 10.7%), assaults ($n = 3$; 5.4%), and sports-related injuries ($n = 1$; 1.8%). As there was only one participant who sustained a sports-related injury, this case was excluded from analyses relating to injury mechanism (it was not felt that this mechanism of injury could be grouped with any other).

PTA durations ranged from less than five minutes to between 12 and 24 hours. Table 5 shows the proportion of mTBI participants in each PTA category.

Table 5: Duration of PTA

PTA Duration	n (%)
< 5 minutes	24 (42.9%)
6 - 60 minutes	10 (17.9%)
61 minutes- 12 hours	13 (23.2%)
12 – 24 hours	9 (16.1%)

All of the mTBI participants had GCS scores recorded at the time of hospital admission, with 3.6% (n = 2) having a GCS score of 13/15; 8.9% (n = 5) having a GCS score of 14/15; and 87.5% (n = 49) having a GCS score of 15/15.

Cerebral CT scans were performed on 76.8% (n = 43) of mTBI participants (all of which showed no abnormalities). All of the mTBI participants who did not undergo a cerebral CT scan had GCS scores of 15/15 at the time of hospital admission.

In terms of PTA, of the 13 mTBI participants who did not undergo a cerebral CT scan, 76.9% (n = 10) reported a PTA of less than 5 minutes, 7.7% (n = 1) reported a PTA of between 6 and 60 minutes and 15.4% (n = 2) reported a PTA of between 61 minutes and 12 hours.

Demographic and injury-related information of the trauma control sample.

The trauma control group were also predominately male (63.2%). Trauma controls had a mean age of 35.32 years (SD 12.54, range 18.06 to 61.02), a mean of 11.49 years of education (SD 2.22, range 9 to 20) and a mean premorbid IQ score (as measured by the Wechsler Test of Adult Reading, WTAR) of 101.47 (SD 8.28, range 80 to 125).

For the trauma controls, the most common mechanism of injury involved motor vehicle accidents (71.9%). Specifically, 33.3% (*n* = 19) were drivers, 7.0% (*n* = 4) were passengers, 22.8% (*n* = 13) were motorcyclists, 5.3% (*n* = 3) were pedestrians, and 3.5% (*n* = 2) were bicyclists. Non-motor vehicle accidents involved falls (*n* = 13; 22.8%), assaults (*n* = 1; 1.8%), stabbings (*n* = 1; 1.8%) and firearms (*n* = 1; 1.8%). For the purpose of analyses, assaults, stabbings and firearm injuries were combined to form one group.

Occupational status of the sample.

In terms of occupation, 13.3% of participants were classed as professionals (*n* = 9 mTBI, 6 trauma controls), 16.8% were employed in managerial/clerical roles (*n* = 8 mTBI, 11 trauma controls), 12.4% were skilled craftsmen (*n* = 8 mTBI, 6 trauma controls), 14.2% were semiskilled operators/servicemen (*n* = 7 mTBI, 9 trauma controls), 27.4% were labourers (*n* = 10 mTBI, 21 trauma controls), 5.3% were students (*n* = 5 mTBI, 1 trauma control), 1.8% were performing fulltime home duties (*n* = 1 mTBI, 1 trauma control), and 8.8% of the sample were unemployed (*n* = 8 mTBI, 2 trauma controls).

The majority of individuals were working at the time of their injury. A total of 70.8% (*n* = 39 mTBI, 41 trauma controls) of participants worked full time and 13.3% (*n* = 3 mTBI, 12 trauma controls) worked part-time or on a casual basis. The remaining participants were full time students (5.3%; *n* = 5 mTBI, 1 trauma control), unemployed and seeking employment (4.4%; *n* = 4 mTBI, 1 trauma control), receiving the disability pension (2.7%; *n* = 2 mTBI, 1 trauma control), performing full time home duties (2.7%; *n* = 2 mTBI, 1 trauma control), or unemployed and not seeking employment (0.9%; *n* = 1 trauma control).

Litigation status of the sample.

At the time of the three month assessment 38.9% (*n* = 23 mTBI, 21 trauma controls) of participants were involved in litigation; and 5.3% (*n* = 3 mTBI and 3 trauma controls) of participants were unsure if they were involved in litigation or not. Of those involved in litigation, 90.9% (*n* = 21 mTBI, 19 trauma controls) of participants were seeking compensation. The remaining 9.1% (*n* = 4) were either not seeking any form of compensation (*n* = 2 mTBI and 1 trauma control) or were unsure whether they were going to pursue compensation at the time of the three month assessment (*n* = 1 trauma control).

Procedure

The initial screen was conducted while participants were inpatients at Westmead Hospital. The majority of the three month assessments were conducted at Westmead Hospital with a small number being conducted in participants' homes or at community mental-health centres. All participants received AU$40.00 at the three month assessment.

Demographic information, such as age, sex, income, occupation and educational history was collected via patient interview (see Appendix B for the interview sheet for both the initial assessment and three month assessment). Information was also collected regarding neurological history (such as diabetes, stroke, epilepsy, cardiac conditions, hypertension), and prior history of TBI. Participants were questioned about any previous or current drug (including alcohol) use, as well as psychological and psychiatric history.

Acute GCS score, cerebral CT scan results, and daily opioid analgesia (administered while an in-patient) were obtained from hospital records.

The order of tests administered was not counterbalanced; however the domain of tests (i.e. psychological versus cognitive) was.

Measures

This study was part of a larger pre-existing project, and therefore many of the predictor variables and procedural aspects were determined prior to the inception of this particular study. Hence there are some discrepancies between the measures used in the current study and those deemed valuable in the preceeding systematic review. For example the systematic review reported that measurement of executive functioning and use of blinded assessors were important, however these are not included in the current study.

Outcome variable – return to productivity.

Pre-injury productivity.

During the initial assessment, participants were asked about their productivity status in the month prior to the accident. Specifically, participants were asked to specify the number of hours spent in paid employment per week in the preceding month, as well as the number of hours spent studying per week (including both private study and face-to-face formal classes) and the number of hours spent performing home duties per week.

Post-injury productivity.

At the three month assessment, participants were asked to specify the average number of hours they currently spent in paid employment. This was then compared to their pre-injury employment hours to determine if there was any change since the accident. Those reporting reduced hours and those reporting no return to employment were combined to form one group due to the small number of participants (n = 3) who fell in the latter category. Participants were also questioned regarding their work duties both at the time of the three month assessment and prior to their accident, with participants classified as either performing similar or reduced duties at work relative to their pre-injury work duties. Hours worked and duties performed were then combined to form one variable to classify participants as having returned to their pre-injury employment level or as having returned at a reduced level/not returned at all.

For those participants who were studying (either at Technical and Further Education (TAFE) or University), information was collected on the average number of study hours per week at the time of the three month assessment. Study hours included both formal lecture time and private study time. This was compared to the average number of study hours per week immediately prior to the accident. For those whose injury was sustained during a semester break (and were therefore not studying at the time of the accident), pre-injury study commitments were recorded as their study commitments in the last month of the previous semester. Similarly, in cases where the three month assessment was conducted during a semester break, post-injury study commitments were recorded as their study commitments in the last month of the previous semester. This data was used to classify participants as either having returned to their pre-injury study commitments or having returned to reduced study commitments/not returned to study at all.

Information was also collected regarding the average number of hours per week spent performing home duties at the time of the three month assessment and compared to the average number of hours per week spent performing home duties during the month prior to the accident. Participants were classified as either having returned to their pre-injury home duties or having returned to a reduced level of home duties/not returned to home duties at all.

The information regarding paid employment, study and home duties was then combined to form one single outcome variable of overall return to productivity. Participants who had returned to their pre-injury work level, study, and home duties were categorised as having returned to their pre-injury productivity level. Participants who reported a reduction in at least one area of functioning (i.e. employment, study or home duties) and those who reported having not returned to any productive activity were combined and categorised as having returned to a reduced level of productivity. A reduction in functioning was classified as either reducing the hours spent performing an activity or reporting any limitation or restriction in one's ability to complete an activity. These groups were combined due to the small number of participants who reported having not returned to any form of productivity (n = 3). The outcome variable was dichotomised in order to produce a robust measure of productivity post-trauma and to allow for an understanding of an individual's overall level of functioning, rather than being limited to understanding only a small part of an individual's productivity.

Pre-injury and injury measures.

Duration of PTA was assessed through retrospective report during the initial assessment and through the use of the Westmead PTA Scale (when available in participants' medical records). Retrospective report was obtained by asking participants "What is the first thing you can remember after the accident?" followed by prompts of "what happened next?" until they were able to relate continuous memory for events following the accident (Gronwall & Wrightson, 1980).

The Injury Severity Score (ISS) is derived from the Abbreviated Injury Scale (AIS; Advancement of Automotive Medicine [AAMI], 1990) and was included as a measure of injury severity. The 1990 revision (AIS-90) was referenced for the current study. The ISS is an anatomical scoring system that provides an overall score of injury severity for patients with multiple injuries. The body is divided into six regions (head and neck, face, chest, abdomen, extremity, and external), and each region is given a score depending on the severity of injury. Scores range from 0 (no injury) to 6 (non-survivable injury). The scores from the three most severely injured body regions are squared and added together to obtain the total ISS, with scores ranging from 0 to 75. A score of six for any single body region results in a final ISS of 75 (Stevenson, Segui-Gomez, Lescohier, Di Scala & McDonald-Smith., 2001). All ISS scores were calculated by AIS trained research psychologists.

Opiate dosages were converted to morphine-based equivalents using the opioid (narcotic) analgesic converter (McAuley; located at GlobalRPh.com). This calculator allows for the equivalent dosages of a range of narcotic analgesics (such as codeine, methadone and fentanyl) to be calculated.

Pain intensity was measured at both assessments through a verbal response scale which determined participants' subjective report of pain at the time of assessment (Jenson & Karoly, 2011). Pain intensity was assessed on an 11 point scale from 0 (*no pain*) to 10 (*pain as bad as it could be*). A common criticism of verbal response scales is the unequal intervals between each score on the scale, such that the difference between "no pain" and "mild pain" may be less than the difference between "moderate pain" and "severe pain" Jensen & Karoly, 2011). Despite this shortcoming, it has been recognised that statistical techniques for analysing such data remain valid, particularly when the scale involves five or more points (Jensen & Karoly, 2011). Strengths of the verbal rating scale include ease of administration, easy to comprehend, good compliance rates, high validity (they correlate well with other measures of pain), as well as being sensitive to treatments which impact on pain intensity (Jensen & Karoly, 2011).

Frequency of headache (Ponsford et al., 2000) since the injury was taken from the Post Concussive Syndrome Checklist (PCSC; Gouvier et al., 1992). Participants in the current study were asked to specify the frequency with which they experienced headaches on a 5 point scale where 1 = *not at all*, 2 = *seldom*, 3 = *often*, 4 = *very often* and 5 = *all the time*. A frequency rating of 3 (*often*) or more was considered to be clinically significant, and hence scores were then dichotomised into those with current headache (i.e. those with scores of 3 or more) and those without (Meares et al., 2008).

Neuropsychological measures.

The WMT (Green et al., 1996) was completed as a measure of effort. The WMT is a computerised measure of verbal learning and memory that contains a number of measures of effort. It involves learning a list of 20 word pairs (e.g. cat - dog) which are presented twice followed by an immediate recognition trial where the participant is required to select each original word from a new word pair (e.g. dog - rabbit). A delayed recognition trial is conducted approximately 30 minutes later where the individual is required to again select each of the original words from a new word pair (e.g. dog - rat). The WMT has been well-researched and investigated in a range of clinical samples including TBI, chronic pain, anosmia, and fibromyalgia (Hartman, 2002). It has also been compared to numerous other tests of effort, including the California Verbal Learning Test, the Test of Memory Malingering, and the Category Test (Hartman 2002). Specific comparison to the

Computerized Assessment of Response Bias revealed an agreement of effort level in 85% of cases (Green et al., 1999). Studies examining the WMT profiles of mTBI patients suggest there are inflated rates of poor effort within this group. Studies have found that mTBI patients are more likely to perform more poorly on the WMT compared to dementia patients, memory impaired children with developmental disorders and intellectual delay (Green et al., 2009), and adults with severe TBI (Green at al., 2009; Flaro, Green and Robertson, 2007). While these studies suggest that mTBI patients are more likely than other populations to exhibit reduced effort, they also demonstrate that the WMT is an effective tool for detecting such instances.

Pre-morbid intellectual functioning was estimated using the WTAR reading test (The Psychological Corporation, 2001) and demographic variables. The WTAR comprises 50 words with irregular spelling which the individual is required to read aloud. Reading pronunciation tests are widely accepted measures of pre-morbid intelligence, as they are known to be resistant to various neurological disorders, such as TBI, mild Alzheimer's disease, Parkinson's disease, Huntington's disease and Korsakoff's syndrome (Green et al., 2008; Mathias, Bowden & Barrett-Woodbridge, 2007). MTBI patients and non brain-injured controls have also been specifically compared in regards to WTAR performance, with no differences found (Mathias, Bowden, Bigler & Rosenfeld, 2007). The WTAR has excellent test-retest reliability in terms of both raw scores obtained ($r = .957$, $p = <.001$) and Full Scale IQ predictions ($r = .969$, $p < .001$) and has been shown to be a stable measure during recovery after traumatic brain injury (Green et al., 2008).

The Westmead Selective Reminding Test (WSRT; Shores, Marosszeky, Sandanam & Batchelor, 1986; Shores, 1995) was included as a measure of verbal learning. It requires the individual to learn a list of 10 words presented over 10 trials. On the first trial the individual is read the 10 words and is required to recall as many words as he or she can (in any order). On all subsequent trials, the individual is read only the words they failed to recall on the preceding trial. They are instructed to recall as many words as possible, including those said on the previous trials. The Consistent Long-Term Retrieval (CLTR) score was used as a measure of verbal learning. The CLTR is a cumulative count of the number of words continuously recalled up until the final trial and is therefore a measure of the ability to learn and retain new verbal material, which is commonly affected following TBI (Echemendia, Putukian, Mackin, Julian & Shoss, 2001; Vanderploeg, Crowell, & Curtiss, 2001). Shores et al. (2008) have reported the WSRT to be sensitive to the effects of mTBI and noted that it demonstrates excellent diagnostic accuracy when comparing mTBI patients and non-brain injured controls. All participants were administered one or the other of two forms (WSRT A or B) (counterbalanced). At the three month assessment participants were re-tested on the version that was not used during their initial assessment. Preliminary analyses revealed that the assumptions of normality, homogeneity of variances and independent samples were all met (see Appendix C); therefore unpaired t-tests were conducted. Raw scores were analysed. The results demonstrated that there were no significant differences in terms of performances on the CLTR for the two versions $t(110) = .746$, $p = .457$ (see Appendix D for complete results of data analysis) therefore scores were collapsed to form one single variable.

The Symbol Digit Modalities Test (SDMT; Smith, 1982) was administered as a measure of information processing speed (Cicerone, 1996; Ponsford et al., 2000). The task consists of an A4 piece of paper with a key at the top of the page which presents nine abstract symbols, each of which is paired with a number from one to nine. The remainder of the page consists of a randomised order of the abstract symbols and the individual is required to either write (as per the written version of the task) or say aloud (as per the oral version of the task) the corresponding number for each symbol in the order presented on the page, according to the key. After completing ten practice items, the individual is given 90 seconds to complete as many items as possible. The oral version was used in the current study to reduce the amount of missing data as a result of orthopaedic injuries which precluded written responding. Raw scores were converted into t-scores for analysis, based on participants' age and years of education (12 years or less; and 13 years or more). Normative data are available from a sample of 1307 normal adults, aged 18 to 78 years, stratified by education (12 years or less; and 13 years or more) and age (Strauss, Sherman & Spreen, 2006). Test-retest reliability is reported to range from .70 - .91 over short periods (i.e. one month) and values of .72 - .79 over longer periods, of up to 2 years (Strauss et al., 2006). The written and oral versions correlate highly with each other at .881 (Ponsford & Kinsella, 1992). The SDMT also correlates highly with other neuropsychological tests. The most similar test is the digit symbol coding subtest from the Wechsler tests, and correlations between these two tests have ranged from .62 - .91 (Strauss et al., 2006). In a study involving head-injured patients, Ponsford and Kinsella (1992) found that the oral version of the SDMT was the best single measure of information processing speed.

An abbreviated version of the California Computerised Assessment Package (CalCAP; Miller, 1990) was administered as a measure of reaction time. The CalCAP is modelled after the Continuous Performance Task and requires individuals to focus on a display field on a computer screen and respond only to a specified stimulus (Miller, 1990). The CalCAP offers both a standard version (10 subtests with an administration time of 20 to 25 minutes) and an abbreviated version (four subtests with an administration time of 8 to 10 minutes). In this study, the abbreviated version was used. This version uses a subset of tests that have been shown to be the most sensitive from the standard version (Miller, 1990). These subtests involve numbers being briefly presented on the computer screen. The current study analysed the Sequential Reaction Time 1 subtest, in which the individual is required to press a key only when they see two sequential number that are the same (for example a 3 immediately followed by another 3). Reaction time raw scores (in milliseconds) were used in the analysis. This subtest also involves working memory as the individual must hold the last digit presented in mind. Miller (1990) reports normative data for the CalCAP from 656 men, with results stratified by age (20-34, 35-44, 45+) and education (<16 years, 16 years, >16 years). Despite the normative sample consisting only of males, it has been shown that males and females perform similarly on all indices of the CalCAP (Durvasula, Miller, Myers, Satz & Wyatt, 1998). Individuals who do not fall within one of the specified age brackets are compared to all normative data available within their educational bracket. Miller (1995) reports that the sequential reaction time task has a test-retest reliability of .68, which is similar to other neuropsychological tests (.47 - .77). Internal consistency has been found to be .86. Processing speed and reaction time are commonly affected following head injury, and computerized measures of these skills have been reported to be more sensitive to subtle abnormalities after head injury than conventional test batteries (Waterloo, Ingebrigtsen & Romner, 1997).

Chapter 7: Results

Univariate Data Analysis

The distributions of the independent variables (age, sex, years of education, demographic-predicted Full Scale IQ score, income, number of previous mTBI's, injury mechanism, morphine dose equivalent administered on the day of the initial assessment, subjective report of pain, length of hospital stay, and compensation/litigation status) were examined in order to ensure that there were no extreme cases which could have an undue influence on the results. There were no outlying cases, defined as ± 2.5SD from the mean (Howell, 2002) and all distributions were approximately symmetrical.

Assumptions of normality, constant variance and linearity were examined. The assumption of normality was examined using the Kolmogorov-Smirnov test and the inspection of Q-Q plots for all continuous and ordinal independent variables (Howell, 2002). The assumption of normality was met for the variables of age at the time of injury and predicted Full Scale IQ score (Howell, 2002). All other variables (length of hospital stay, years of education, pain intensity at the time of the assessment, and morphine-based equivalents administered on the day of the assessment) did not assume a normal distribution (see Appendix E for Q-Q plots and relevant output). It should be noted that the assumption of normality is not made when variables are used as independent variables (Cohen, Cohen, West & Aiken, 2003). In the preliminary analyses that are reported below, these variables were treated as dependent variables.

Demographic and Injury Characteristics of Mild TBI and Trauma Control Groups

MTBI and trauma control groups were compared on a number of demographic and injury-related variables. Independent sample t-tests were used to compare the groups on the continuous variables of age and predicted Full Scale IQ score (Hosmer & Lemeshow, 2000). Mann-Whitney *U* tests were performed for the variables of years of education, morphine based equivalents administered on the day of the assessment, pain and length of hospital stay, as these variables did not meet the assumption of normality required for a t-test. Chi-square analyses were performed for the categorical variables of sex, number of previous mTBI's, and litigation status. Exact tests were calculated for the categorical variable of income and injury mechanism, because of the small expected frequencies in some of the cells.

Bonferroni adjustments were made to control for the number of comparisons, with the alpha level set at 0.005 to give an overall rejection rate of 0.05. No significant group differences were found. Overall these results suggested that the mTBI and trauma control groups were well-matched on both demographic and injury-related variables. These results are presented in Table 6.

Table 6: Demographic and injury characteristics of mTBI (n=56) and Control (n=57) groups

Variable	Group Comparison mTBI n(%)	Trauma Controls n(%)	p-value
Pre-Injury Variables			
Age (y) mean (SD)	36.3 (14.4)	35.3 (12.5)	.704
Sex (Female)	17 (30.4)	21 (36.8)	.465
Years Education mean (SD)	11.64 (2.9)	11.49 (2.2)	.713
Predicted Full Scale IQ mean (SD)	100.3 (10.5)	101.5 (8.3)	.518
Income			.025
0-$10.39K	12 (21.8)	3 (5.4)	
10.4-25.99K	8 (14.5)	10 (17.9)	
$26-36.39K	12 (21.8)	9 (16.1)	
$36.4-46.79K	10 (18.2)	14 (25)	
$46.8-77.99K	9 (16.4)	13 (23.2)	
>$78K	4 (7.3)	7 (12.5)	
No. of previous mTBI's			.012
0	33 (58.9)	46 (80.7)	
1 or more	23 (41.1)	11 (19.3)	
Injury Variables			
Injury Mechanism			.105
MVA driver	18 (32.7)	19 (33.3)	
MVA passenger	14 (25.5)	4 (7.0)	
MVA motorcyclist	8 (14.5)	13 (22.8)	
MVA other	6 (10.9)	6 (10.5)	
Fall	6 (10.9)	12 (21.1)	
Assault	3 (5.5)	3 (5.3)	
CT brain scan			
Not performed	13 (23.2)		
Normal	43 (76.8)		
GCS on admission			
13	2 (3.6)		
14	5 (8.9)		
15	49 (87.5)		
PTA Duration			
< 5 minutes	24 (42.9)		
6-60 minutes	10 (17.9)		
61 mins – 12 hrs	13 (23.2)		
12-24 hrs	9 (16.1)		
Post-Injury Variables			

Morphine dose equivalents mean (SD)	49.52 (87.57)	39.52 (38.10)	.981
Pain mean (SD)	3.23 (2.27)	3.98 (2.74)	.147
Length of Hospital Stay, days mean (SD)	6.3 (4.9)	8.3 (8.3)	.138
Involved in Litigation/Compensation (yes)	23 (43.4)	20 (37.7)	.553

Productivity Status Before and After Trauma

Participants were questioned regarding the number of hours spent in paid employment, undertaking formal study (i.e., University or TAFE) and performing home duties during the month prior to the accident and during the month immediately preceding the 3 month assessment. The mean number of hours spent performing each activity (employment, study and home duties) is presented in Table 7, along with the reduction in hours for each area and the total change in hours taking employment, study and home duties into account.

Analyses using paired sample t tests were first conducted with each group separately to determine if the reduction in hours for each activity was significant. The results revealed that the reduction in employment hours was significant for both the mTBI group $t(46) = 4.05$, $p < .0005$, and for the trauma control group $t(54) = 7.035$, $p < .0005$. The reduction in hours spent in formal study was not significant for either the mTBI group $t(13) = 1.508$, $p = .15$, or for the trauma control group $t(6) = 1.61$, $p = .16$. Analysis of the changes in hours spent performing home duties revealed significant differences for both the mTBI group $t(55) = 2.373$, $p = .02$, and for the trauma control group $t(54) = 4.171$, $p < .0005$.

Independent sample t-tests were conducted to determine if the average change in hours for each activity was different for the mTBI and trauma control groups. As can be seen in Table 7, the trauma control group reported reducing their employment hours and hours spent performing home duties significantly more than did members of the mTBI group. There was no significant difference between the average reduction in study hours for each group. However, given the small sample size for the analysis of the change in study hours (n=14 mTBI; n=7 trauma controls), the lack of a significant finding could reflect reduced power. Table 7 shows that those in the trauma control group reduced their overall level of productivity to a significantly greater degree than did those in the mTBI group.

Table 7: Comparison of average employment, study, home duty hours and overall productivity hours for mTBI and trauma controls pre-injury and post-injury.

Productivity Measure	Group Comparison mTBI mean (SD)	Trauma Control mean (SD)	df	p Value
Paid Employment Hours	(n=47)	(n=55)		
Pre-Injury	41.4 (13.4)	43.9 (12.6)		
Post-injury	30.8 (20.4)	24.7 (22.5)		
Change in hours	-10.6 (17.9)	-19.2 (20.2)	100	.026*
Study Hours	(n=14)	(n=7)		
Pre-injury	14.8 (12.8)	13.3 (11.0)		
Post-injury	13.7 (12.9)	9.1 (11.8)		
Change in hours	-1.1 (2.7)	-4.2 (6.8)	7	.293
Home Duties	(n=56)	(n=55)		
Pre-injury	9.8 (9.0)	10.9 (9.3)		
Post-injury	8.9 (8.7)	7.7 (7.5)		
Change in Hours	-0.9 (2.9)	-3.2 (5.7)	81	.011*
Overall Productivity	(n=56)	(n=57)		
Change in Hours	-10.0 (17.7)	-22.1 (21.8)	107	.002*

* $p < .05$.

Effect of PTA on Return to Productivity

For the mTBI group, the effect of PTA duration on return to productivity was examined. Chi square analysis was used to examine the number of cases in each group. An exact test was then used to examine the relationship between PTA duration and return to productivity due to the small expected frequencies in some groups. The results of the analysis revealed that PTA duration did not significantly predict return to productivity status in the mTBI group, $\chi^2(3,56) = 5.08$, $p = .162$. Results of the chi-squared analysis are presented in Appendix F.

Unadjusted Bivariable Prediction of Return to Productivity

The bivariate Pearson correlations of the independent variables (age, sex, years of education, predicted Full Scale IQ score, income, number of previous mTBI's, injury mechanism, either opiates administered on the day of the initial assessment or morphine based equivalents, pain intensity, length of hospital stay, and compensation/litigation status) were examined to assess for evidence of multicollinearity. According to Tabachnick and Fidell (2001), multicollinearity can become problematic when correlations are greater than 0.7. The results of this analysis revealed that the highest bivariable correlation was 0.427, ($p < .0005$) hence all independent variables were included in the logistic regression analyses. It should, however, be noted that multicollinearity can also arise when two or more independent variables have a high multiple correlation with another independent variable, and hence the pair wise test is not definitive (Dielman, 2001).

Independent variables associated with pre-injury/demographics (age, sex, years of education, and previous mTBI), injury (ISS), post-injury (subjective report of pain, headache, length of hospital stay, and litigation status) and neuropsychological measures (verbal learning, processing speed, and reaction time) were entered one at a time with the mTBI/trauma control grouping variable.

Bivariate analyses, which examined the relationship between return to productivity and each independent variable separately, were carried out using logistic regression. The group variable (mTBI or trauma control) was held constant in each case. Effect sizes are not reported in the following analyses because odds ratios have been reported instead. As noted by Breaugh (2003) many statisticians (including Haddock, Rindskopf & Shadish, 1998; and Pampel, 2000) have advocated reporting the odds ratio rather than effect sizes as one desirable property of an odds ratio is that "it's possible range of values is not influenced by the marginal distributions of the variables" (Rudas, 1998 p10). Table 8 presents the results of these analyses. The results revealed that pain, length of hospital stay, verbal learning (WSRT, CLTR) and litigation status were all predictive of full return to productivity. Participants' subjective report of pain was negatively associated with a full return to productivity in that for every one unit increase in participants' report of subjective pain, the odds of a full return to productivity decreased by a factor of 0.852. Length of hospital stay was also negatively associated with a full return to productivity in that for every one unit increase in length of hospital stay, the odds of a full return to productivity decreased by a factor of 0.886. Verbal learning (as assessed by the WSRT, CLTR measure) was positively associated with a full return to productivity, in that for every one unit increase in verbal learning (as verbal learning improved), the odds of a full return to productivity increased by a factor of 1.023. Litigation status at three months post-injury was negatively associated with a full return to productivity. The odds of a full return to productivity for those who were actively involved in either litigation or seeking compensation was 0.213 times lower than that of those who were not involved in any litigation or seeking compensation.

Table 8: Bivariate associations of mTBI (n= 56) and trauma controls (n= 57) participants with full return to productivity at 3 months following hospitalisation.

	Full Return to Productivity (n=55)				
Variable	OR	95% CI	Wald χ^2	df	p Value
Pre-Injury Variables					
Age (y) mean (SD)	.989	.96 - 1.017	.615	1	.433
Sex (Female)	1.001	.444 - 2.260	.000	1	.998
Years Education	.981	.846 - 1.138	.063	1	.802
Previous mTBI (yes)	2.065	.867 - 4.918	2.681	1	.102
Injury Variables					
Injury Severity Scale Score	.957	.897 - 1.021	1.755	1	.185
Pain[a]	.852	.742 - .979	5.126	1	.024 *
Post-Injury Variables					
Headache >3[b]	.965	.379 - 2.455	.006	1	.940
Length of Hospital Stay, days	.886	.803 - .977	5.887	1	.015*
Litigation/Compensation (yes)	.213	.087 - .524	11.362	1	.001*
Neuropsychological variables					
WSRT CLTR	1.023	1.002 - 1.044	4.797	1	.029*
SDMT Oral T	1.009	.969 - 1.049	.176	1	.675
CalCAP Seq RT1	.999	.995 - 1.003	.451	1	.502

* $p < .05$.

[a] Pain – participants' subjective report of pain at the time of the initial assessment.

[b] Headache >3 – participants' subjective report of headache frequency of "often" or more (from 5 point scale ranging from "1=not at all" to "5=all the time").

Multivariable Analysis of Return to Productivity

Measures which were found to significantly predict a full return to productivity in the bivariate associations (participants' subjective report of pain, length of hospital stay, verbal learning and litigation status) were fitted into a final multivariable logistic regression model. Interactions between each independent variable and group membership (mTBI or trauma control) were also examined. When the full model with all interactions was fitted, three cases were found to have standardized residuals greater than 2.0 standard deviations. These three cases were examined in the dataset and subsequently excluded from the final analysis to eliminate the effects of any undue influence. The full model with interactions was then re-fitted without these three cases. The final model was then reduced through a process of backward elimination, whereby the least significant variable was removed from the model and the model then re-fitted. The interaction between group and litigation status was found to be non-significant ($p = .387$) and therefore this interaction was removed and the model re-fitted. The new model revealed that the interaction between group and participants' subjective report of pain was not significant ($p = .078$) and hence this was removed from the model and the model was again re-fitted. At this point, all variables were significant at the .05 level. The results of the final model are presented in Table 9.

In the final multivariable model, participants' subjective report of pain remained a significant predictor of return to productivity with higher levels of pain associated with a reduced likelihood of a full return to productivity. Length of hospital stay also remained a significant predictor of return to productivity with longer hospital stays associated with a reduced likelihood of a full return to productivity for the mTBI group only. This relationship was not found for the trauma control group and the interaction between length of hospital stay and group was significant, suggesting that the association between length of hospital stay and return to productivity was significantly different for mTBI and trauma control groups. Correlational analyses between length of hospital stay and injury severity, as measured by the Injury Severity Scale (ISS) were then examined for each group (mTBI and trauma controls) separately. While these analyses revealed a significant correlation between ISS and length of hospital stay for both groups (correlation for the mTBI group = .443, p = .001; correlation for trauma controls = .300, p = .028), the correlation was much stronger for the mTBI group. Stronger verbal learning was associated with an increased likelihood of full return to productivity for the mTBI group; however this relationship was not seen for the trauma controls. A significant interaction between verbal learning and group membership was found. Being involved in litigation or in seeking compensation at three months post-injury was also a significant predictor of return to productivity, with those involved in either litigation or compensation being significantly less likely to have returned to full productivity by three months post-injury (regardless of group membership).

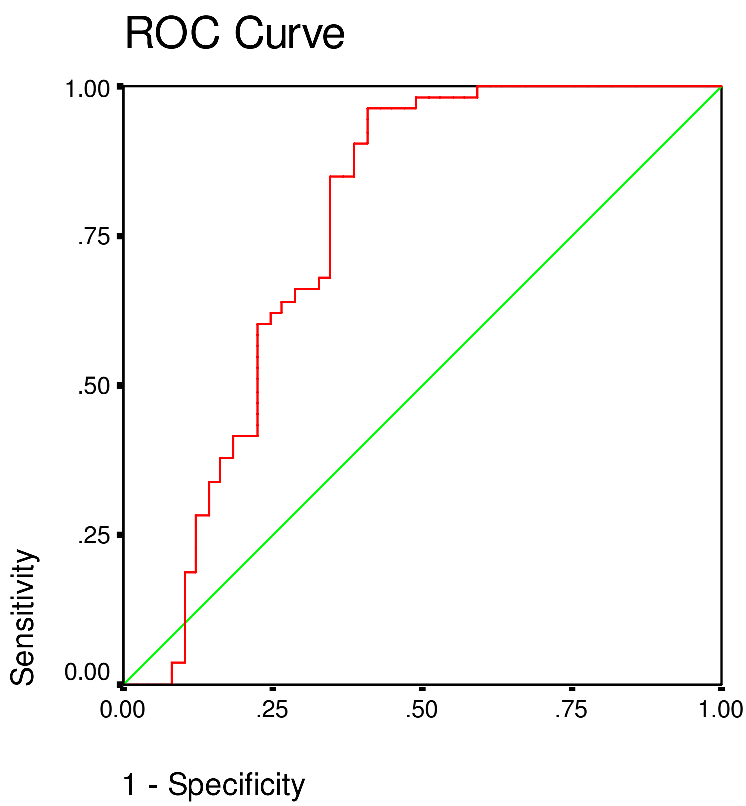
Table 9: Final multivariable model with the predictor of full return to productivity (n=55) for mTBI and trauma patients at 3 months post-injury

Variable	Full Return to Productivity OR	95%CI	p Value	Effect size (Cohen's d)
Pain	.755	.582 - .980	.034 *	0.48
Length of Hospital Stay (mTBI)	.570	.368 - .884	.012 *	0.28
Length of Hospital Stay (Controls)	.966	.847 - 1.102	.607	0.74
Length of Hospital Stay x Group	1.695	1.072 - 2.679	.024 *	
WSRT CLTR (mTBI)	1.103	1.023 - 1.188	.010 *	0.10
WSRT CLTR (Controls)	1.012	.982 - 1.044	.432	1.23
WSRT CLTR x Group	.918	.847 - .994	.036 *	
Litigation/Compensation (yes)	.143	.047 - .435	.001 *	0.73

* $p < .05$.

A receiver operating characteristic (ROC) curve analysis was conducted to determine the accuracy of the final multivariable model in discriminating between those who returned to full productivity and those who did not. The ROC curve is presented in Figure 2.

Figure 4: ROC curve analysis of the final multivariable model.



The ROC curve analysis revealed that the area under the curve was 0.761, indicating that the productivity status of 76.1% of participants could be correctly classified using the current multivariable model. A ROC curve analysis plots the probability of detecting a true positive and a false positive for all different possible cutpoints (Hosmer & Lemeshow, 2000). The area under the ROC curve ranges from zero to one, and this value is the model's ability to discriminate between subjects who experience the outcome of interest (in this case full return to productivity) and those who do not (Hosmer & Lemeshow, 2000). A value of 0.5 represents a model with no discrimination, and hence is no better at predicting the outcome than chance (Fawcett, 2006; Hosmer & Lemeshow, 2000; Marzban, 2004; Metz, 1978). Values between 0.7-0.8 are considered to represent “acceptable” discrimination; values between 0.8-0.9 are considered to represent “excellent” discrimination; and values above 0.9 represent “outstanding” discrimination (Hosmer & Lemeshow, 2000). Areas under the ROC curve of greater than 0.9 are extremely unusual (Hosmer & Lemeshow, 2000). Based on this classification, the final multivariable model represents an “acceptable” level of discrimination and accounts for some but not all of the variance in return to full productivity following trauma.

Chapter 8: Discussion

Changes in Productivity

The first hypothesis that participants from the mTBI group would be less likely to have returned to their pre-injury productivity levels by three months post-injury as compared to trauma controls was not supported. Interestingly, however, significant between-group differences in post-injury productivity status were found.

Paid employment.

Both the mTBI and the trauma control groups significantly reduced the number of hours they spent in paid employment at three months post-injury. There was a significant difference in the size of the reduction between the two groups; however, this difference was not in the direction expected, with the trauma control group reducing their employment hours significantly more than the mTBI group. This is in contrast to the findings of Friedland and Dawson (2001) who reported no differences in return to work rates for mTBI as compared to a trauma control group. It is unclear why in the present study the trauma control group reduced their employment hours significantly more than did the mTBI group. As previously mentioned there were no significant differences between the two groups on important variables which may influence return to productivity such as age, education, post injury medication, pain or litigation/compensation-seeking status. Group differences such as site and severity of physical injuries, or type of employment (e.g. clerical, labourer etc.) may have influenced the current result. Future studies should further explore this finding.

Study hours.

Neither the mTBI group nor the trauma control group were found to have significantly reduced the number of hours they spent in formal study at three months post-injury. As previously mentioned, the small number of participants involved in formal study (*n* = 14 mTBI participants; *n* = 7 trauma control participants) would make it difficult to find a significant change. Extension of this study to focus exclusively on University or TAFE students would allow for a greater level of understanding of the effect of trauma on resumption of studies.

Home duty hours.

Both the mTBI and the trauma control groups had significantly reduced the number of hours they spent performing home duties at three months post-injury. It is reasonable to expect that individuals would reduce the number of hours spent performing home duties, especially during the first few weeks following their injury. The literature suggests that most mTBI patients have recovered with only minimal, if any ongoing difficulties by three months post-injury (Moore et al., 2006). Most studies examining return to productivity have chosen to selectively focus on employment, and to a lesser extent study, with the area of home duties often being overlooked. Further studies examining this area in greater detail would help elucidate the relationship between traumatic injuries and their effects on home duties. Unexpectedly, the trauma control group was found to have reduced the time spent performing home duties significantly more than the mTBI group had. The trauma control group consisted of a physically injured trauma group, and the presence of these injuries may have contributed to this group being less able to return to their home duties as compared to the mTBI group.

PTA Duration and Return to Productivity

The second hypothesis, that longer PTA duration would be predictive of reduced likelihood of a full return to productivity at three months post-injury for the mTBI group was not supported. The majority of studies which have examined this area have focused on moderate and severe TBI groups. One study which did examine an mTBI group failed to find an association between PTA duration and vocational status three to four months post-injury (Paniak et al., 2000). Similar results have been reported for a mild to moderate TBI group (Goranson, Graves, Allison & La Freniere, 2003) and a moderate to severe TBI group (Sherer et al., 2003). However a range of studies have found PTA to be a significant predictor of productivity status when productivity was assessed at 12 months post-injury for both moderate and severe TBI groups (Brown et al., 2005; Fleming, Tooth, Hassell and Chan, 1999; Sherer et al., 2002; Van der Naalt et al., 1999). It is possible that the limited range of PTA duration within an mTBI group rendered this variable nonsignificant.

Demographic Variables and Return to Productivity

The third hypothesis stated that the demographic variables of older age at the time of injury, fewer years of education, and lower pre-morbid intellectual functioning would all be associated with a reduced likelihood of a full return to productivity at three months post-injury for both the mTBI and the trauma control groups. This hypothesis was not supported. The literature examining age as a predictive factor in return to productivity demonstrates mixed support for this association, with studies typically finding either no association (Bazarian et al., 2010; Nolin & Heroux, 2006; Ruffolo et al., 1999; Stranjalis et al., 2004; Vanderploeg, Curtiss, Duchnick & Luis, 2003) or a negative relationship (Dawson et al., 2004; Guerin et al., 2006; Hanlon et al., 1999; Paniak et al., 2000) between age and return to productivity. Further examination of reasons for these differing results would be valuable. The lack of an association between education and return to productivity replicates a number of previous studies (Drake et al., 2000; Guerin et al., 2006; Ruffolo et al., 1999; Vanderploeg et al., 2003). Higher levels of education have been found to be predictive of return to work following mTBI in a number of studies (Rimel et al., 1981; Stulemeijer et al., 2008) and hence this relationship deserves further examination. Future studies may wish to examine whether this relationship is mediated by other factors such as income or job status. The lack of a significant relationship between premorbid IQ and return to productivity replicates the findings reported by Drake et al. (2000). Conflicting results have been reported by Vanderploeg et al. (2003) where higher premorbid IQ was associated with a higher likelihood of return to productivity. The limited number of studies examining this area precludes firm conclusions to be drawn and therefore further research is warranted.

The fourth hypothesis, that sex would not be associated with return to productivity was supported. This finding is in line with a number of previous studies (Bazarian et al., 2010; Guerin et al., 2006; Hanlon et al., 1999; Nolin & Heroux, 2006; Paniak et al., 2000; Rimel et al., 1981; Ruffolo et al., 1999; Stranjalis et al., 2004; Stulemeijer et al., 2008), providing strong evidence that neither sex is more likely to return to productivity following an mTBI.

Injury-Related Variables and Return to Productivity

The fifth hypothesis focused on injury-related variables and stated that participants' subjective reports of elevated pain, the presence of headaches and longer length of hospital stay would be associated with a reduced likelihood of a full return to productivity at three months post-injury for both the mTBI and trauma control groups. This hypothesis was partially supported with participants' subjective report of pain and length of hospital stay being significant predictors of return to productivity both when examined separately and when fitted into the multivariable logistic regression model.

Relationship between pain and return to productivity.

Participants who reported higher levels of pain were less likely to have returned to full productivity by three months post-injury as compared to those who reported less pain. There was no difference in this relationship between groups, suggesting that pain affects return to productivity for both mTBI and trauma controls. It is important to note that pain is not simply regarded as physical but also involves an emotional component. Four dimensions of pain have been described which include the intensity (how much it hurts), affect (degree of emotional arousal and readiness to react), quality (the type of pain, for example, throbbing, stabbing etc.) and location (on the body) of pain (Jensen & Karoly, 2011). Both sensory and cognitive aspects of pain may influence one's ability to return to productivity after trauma.

The underlying explanation for why pain may affect an individual's return to productivity may be gained from theories of attention which propose that individuals have a limited pool of resources which they can devote to stimuli (Kuhajda, Thorn & Klinger, 1998). Therefore when attention is given to one task, there is less attention available to give to a simultaneous task. When this is related to the area of pain, it is suggested that processing pain is a demanding task which requires attentional resources (Kuhajda et al., 1998). Hence individuals who are experiencing pain are less able to adequately attend to other tasks. This theory has received support from numerous studies which have found that individuals who experience pain are less able to perform other cognitive tasks, such as those involving attention (Seminowicz & Davis, 2007; Taylor et al., 1996); encoding and memory (Kuhajda et al., 1998; Kuhajda et al., 2002); efficient processing of new information (Grigsby et al., 1995), and decision-making (Ji et al., 2010). Reduced attention, poor memory, slowed information processing speed and reduced decision-making capacity are all likely to impact upon an individual's ability to return to their pre-injury productivity levels. Indeed, Serlin, Mendoza, Nakamura, Edwards and Cleeland (1995) suggest that once an individual's pain passes a certain threshold it becomes difficult for them to ignore and therefore becomes a primary focus of their attention, which can prohibit many daily activities.

Avoidance behaviour is common in chronic pain (Norton & Asmundson, 2004). The fear of pain, which is driven by the anticipation of pain as opposed to sensory experience of pain maintains the avoidance behaviours, and has been found to impact on one's functional ability (Al-Obaidi, Nelson, Al-Awadhi & Al-Shuwaie, 2000).

Additionally, pain also commonly co-occurs with other psychological conditions. Mooney et al. (2005) found that only 2% of their sample suffered pain without any other diagnoses, compared to 58% of their sample who suffered from pain in addition to some form of psychiatric disorder. Hoffman (2007) found that higher levels of pain at one year post-injury were associated with greater levels of depression at inpatient rehabilitation in a sample of patients with mild to severe TBI. Furthermore depression was found to influence the relationship between pain and community integration at one year post-TBI (Hoffman et al., 2007). Chronic pain has also been found to be associated with symptoms of PTSD (Nampiaparampil, 2008). Specifically Bryant, Marosszeky, Crooks, Baguley & Gurka (2007) found that 37% of their sample with chronic pain met criteria for PTSD compared to only 15% without pain, which was a significant difference. Although speculative, it is possible that the relationship between pain and return to productivity may be linked with the higher prevalence of psychiatric conditions in those experiencing higher levels of pain.

Length of hospital stay and return to productivity.

A significant interaction was found between length of hospital stay and group membership in relation to return to productivity, with length of hospital stay being a significant predictor of return to productivity for the mTBI group but not for the trauma controls. For the mTBI group, a longer hospital stay was associated with a reduced likelihood of a full return to productivity by three months post-injury. Length of stay has been reported to be a significant predictor of return to productivity when TBI patients of varying severities (mild to severe) have been grouped together (Cifu et al., 1997; Keyser-Marcus et al., 2002; Sander, Kreutzer, Rosenthal, Delmonico & Young, 1996). Friedland and Dawson (2001) reported that shorter length of hospital stay was associated with greater likelihood of return to work when examining their mTBI and trauma control groups as a whole; unfortunately the groups were not analysed on this variable separately. Future studies may wish to examine length of hospital stay for both mTBI and trauma controls to further explore the current findings.

Neuropsychological Performance and Return to Productivity

The study's sixth hypothesis, that performances on tasks of verbal learning, information processing speed and reaction time would be positively associated with full return to productivity at three months post-injury for the mTBI group was partially supported, with a significant result being found for verbal learning.

The area of verbal learning and verbal memory in the prediction of return to productivity has received mixed results in the literature. The current finding is in line with a number of studies which have examined the relationship between verbal memory and occupational outcomes for TBI patients (Boake et al., 2001; Cifu et al., 1997; O'Connell, 2000; Tate & Broe, 1999). Similar results have also been found for other clinical populations, including schizophrenia (McGurk, Mueser, Harvey, LaPuglia & Marder, 2003), systemtic lupus (Panopalis et al., 2007) and bipolar disorder (Dickerson et al., 2004). It is important to note that most of the above-mentioned studies have focused on delayed verbal memory rather than on verbal learning, which was the variable of interest in the current study.

The finding that verbal learning significantly predicted return to productivity in the mTBI group is consistent with literature demonstrating that measures of verbal learning are able to differentiate between mild, moderate and severe TBI patients and non-head injured controls (Echemendia et al., 2001, Shores et al., 2008; Vanderploeg et al., 2001). When compared to non-head injured controls, TBI patients have been shown to have slower rates of learning new information (DeLuca, Schultheis, Madigan, Christodoulou & Averill, 2000), more difficulty consolidating new information, in that they tend to forget new material more rapidly (Vanderploeg et al., 2001), and are less likely to employ organisational strategies to aid learning (Crosson, Novack, Trenerry & Craig, 1988). The measure used in the current study (WSRT) has been reported to significantly differentiate between mTBI patients that presented to an Emergency Department and non-brain injured Emergency Department presentations (Shores et al., 2008).

There is a correlation between intelligence and verbal learning skills, in that individuals with higher intelligence tend to perform better on tasks of verbal learning (Rapport et al., 1997). The finding in the current study that verbal learning predicted return to productivity for mTBI patients may suggest that brighter people (i.e. those with better performance on tasks of verbal learning) are better able to cope with the demands of high productivity or that individuals with faster recovery are better able to return to productivity. The current results are unable to determine which of these may be the case and further research is warranted to explore this association in more depth.

Litigation and Return to Productivity

The study's seventh hypothesis, that being involved in either litigation or in seeking financial compensation would be associated with a significantly reduced likelihood of returning to full productivity by three months post-injury, was supported. This result was found for both mTBI patients and trauma controls and is consistent with previous studies which have found that seeking some form of financial incentive following mTBI is associated with reduced likelihood of returning to pre-injury employment (Paniak et al., 2000; Reynolds et al., 2003). Furthermore, the longer an individual is involved in either litigation or in seeking compensation, the slower is their return to work (Reynolds et al., 2003).

In the current study, being involved in litigation or in seeking compensation was not related to initial injury severity (as measured by the ISS), nor was it related to participants' subjective report of pain. Therefore, at least based on these two measures, it does not seem that litigation or compensation seeking was a result of having sustained a more serious injury or having experienced more serious post-injury pain.

There are, however a number of other possible explanations as to why those involved in litigation or in seeking compensation may be less likely to return to their pre-injury productivity levels. It is possible that individuals who are involved in litigation or in seeking compensation may have been less inclined to return to their pre-injury productivity levels for fear that their financial payments may be impacted. Another possibility is that individuals involved in seeking financial incentives are more likely to view their current functioning as sub-optimal when compared to non-seeking individuals (Lees-Haley et al., 1997). This in turn could result in litigating or compensation-seeking individuals believing that they are not functioning at a level that would enable them to return to their pre-injury productivity levels, regardless of whether or not they were actually capable of doing so.

Hence the current study provides further support for a link between seeking some form of financial incentive and a reduced likelihood of returning to one's pre-injury productivity levels at three months post-injury. It does not, however allow for a detailed analysis of underlying reasons for this association.

Understanding Return to Productivity

When examined in a multivariable model the four predictors detailed above (pain, length of hospital stay, verbal learning and litigation/compensation seeking) correctly classified just over 76% of all participants as having either returned or not returned to their pre-injury productivity level. These measures should be used to assist those involved in rehabilitation to understand return to productivity.

Limitations and Future Directions

There are a number of limitations to the current study that warrant mention. The study was designed to focus on early post-injury outcomes in mTBI and therefore involved only a three month follow-up interval. While three months is an appropriate follow-up period due to the fact that the majority of individuals who have sustained an mTBI have fully recovered in that time frame, the extension of the follow-up to twelve months may have allowed for further understanding of specific issues. For example a longer follow-up would have allowed the researchers to examine continuity of employment, retention and change or lack of change in employment factors such as reduced hours of work.

No information was collected from subjects who declined to participate in the three month follow-up assessment. From a productivity perspective it may have been valuable to have briefly questioned these participants about their productivity status. This would have allowed for comparisons to have been made regarding productivity status between those who did and did not continue in the study. Participants were not questioned as to why they had not returned to work, study or home duties. Collection of this information would have provided useful qualitative data.

Participants' PTA duration was collected through retrospective report. It should be acknowledged that prospective measurement of PTA is considered to result in a more accurate measurement of PTA duration (Meares, Shores, Taylor, Lammél & Batchelor, 2011; Ponsford et al., 2004; Shores et al., 2008).

The relationship between post-TBI productivity status and psychological/psychiatric state was not examined. It is possible that depression, anxiety, PTSD or other psychiatric conditions could have impacted upon participants' ability to return to productivity; and hence inclusion of this variable may well have improved classification accuracy.

In summary, the results of the current study enabled identification of a number of factors that predict an individual's likelihood of returning to their pre-injury productivity by three months post-injury. Specifically, a lower level of subjective pain and not being involved in either litigation or compensation-seeking as a result of the injury were both predictive of an increased likelihood of returning to one's pre-injury productivity for both mTBI and trauma controls. Additionally, a shorter hospital admission and stronger verbal learning skills were found to be predictive of a higher likelihood of returning to pre-injury productivity status for the mTBI group.

The area of mTBI is a challenging one to research due to the heterogeneity of the group, and varying recovery observed. The fact that the majority of TBI's are in the mild category also makes this area very important to understand, due to the high number of individuals who sustain mTBI's each year. There are many factors which contribute to how an individual will recover following an mTBI, and it is important to have a thorough understanding of a patient's circumstances in order to best predict their outcome. This research has provided some valuable insights into the area of post-injury productivity for both mTBI patients and non head-injured trauma patients; however questions still remain, and therefore more detailed research within this area would greatly aid in the understanding of this complex patient group.

References

Abrams, D., Barker, L.T., Haffey, W. & Nelson, H. (1993). The economics of return to work for survivors of traumatic brain injury: vocational services are worth the investment. *Journal of Head Trauma Rehabilitation*, 8(4), 59-76.

Access Economics (2009). The economic cost of spinal cord injury and traumatic brain injury in Australia. http://www.vni.com.au/sitebuilder/about/knowledge/asset/files/99/final_vni_ report _22julsml.pdf. Accessed on 13/04/2011.

Al-Obaidi, S.M., Nelson, R.M., Al-Awadhi, S. & Al-Shuwaie, N. (2000). The role of anticipation and fear of pain in the persistence of avoidance behavior in patients with chronic low back pain. *Spine*, 25(9), 1126-1131.

American Congress of Rehabilitation Medicine (1993). Definition of mild traumatic brain injury. *Journal of Head Trauma Rehabilitation*, 8(3), 86-87.

American Psychiatric Association. (1994). *Diagnostic and statistical manual of mental disorders* (4th ed.). Washington, DC.

Association for the Advancement of Automotive Medicine. (2001). *Committee on Injury Scaling. The Abbreviated Injury Scale*-1990 revision. Illinois.

Australian Bureau of Statistics (ABS) (1993). *Disability, Ageing & Carers. Brain Injury and Stroke. (ABS Catalogue No. 4437.0).* Canberra: Commonwealth of Australia, 1993.

Australian Bureau of Statistics (ABS) (2007). *National survey of mental health and well-being: summary of results. (ABS Catalogue No. 4326.0).* Canberra: Commonwealth of Australia, 2007.

Barkhoudarian, G., Hovda, D.A. & Giza, C.C. (2011). The molecular pathophysiology of concussive brain injury. *Clinical Sports Medicine*, 30, 33-48.

Bazarian, J.J., Blyth, B., Mookerjee, S., He, H. & McDermott, M.P. (2010). Sex differences in outcome after mild traumatic brain injury. *Journal of Neurotrauma*, 27, 527-539.

Belanger, H.G., Curtiss, G., Demery, J.A., Lebowitz, B.K. & Vanderploeg, R.D. (2005). Factors moderating neuropsychological outcomes following mild traumatic brain injury: a meta-analysis. *Journal of the International Neuropsychological Society*, 11, 215-227.

Bergsneider, M., Hovda, D.A., Lee, S.M. Kelly, D.F., Vespa, P.M., Lee, J.H., Martin, N.A., Phelps, M.E. & Becker, D.P. (2000). Dissociation of cerebral glucose metabolism and level of consciousness during the period of metabolic depression following human traumatic brain injury. *Journal of Neurotrauma,* 17, 89–401.

Berry, D.T.R., Wetter, M.W., Baer, R.A., Youngjohn, J.R., Gass, C.S., Lamb, D.G., Franzen, M.D., MacInnes, W.D. & Buchholz, D. (1995). Overreporting of closed-head injury symptoms on the MMPI-2. *Psychological Assessment*, 7(4), 517-523.

Bianchini, K.J., Curtis, K.L. & Greve, K.W. (2006). Compensation and malingering in traumatic brain injury: a dose-response relationship? *The Clinical Neuropsychologist*, 20, 831-847.

Binder, L.M. (1993). Assessment of malingering after mild head trauma with the Portland digit recognition test. *Journal of Clinical and Experimental Neuropsychology*, 15(2), 170-182.

Binder, L.M. & Rohling, M.L. (1996). Money matters: a meta-analytic review of the effects of financial incentives on recovery after closed-head injury. *The American Journal of Psychiatry*, 153(1), 7-10.

Binder, L.M., Rohling, M.L. & Larrabee, G.J. (1997). A review of mild head trauma. Part I: meta-analytic review of neuropsychological studies. *Journal of Clinical and Experimental Neuropsychology,* 19(3), 421-431.

Boake, C., McCauley, S.R., Levin, H.S., Contant, C.F., Song, J.X., Brown, S.A., Goodman, H.S., Brundage, S.I., Diaz-Marchan, P.J. & Merritt, S.G. (2004). Limited agreement between criteria-based diagnoses of postconcussional syndrome. *The Journal of Neuropsychiatry and Clinical Neurosciences,* 16, 493-499.

Boake, C., McCauley, S.R., Levin, H.S., Pedroza, C., Contant, C.F., Song, J.X., Brown, S.A., Goodman, H., Brundage, S.I. & Diaz-Marchan, P.J. (2005). Diagnostic criteria for postconcussional syndrome after mild to moderate traumatic brain injury. *The Journal of Neuropsychiatry and Clinical Neurosciences*, 17, 350-356.

Boake, C., McCauley, S.R., Pedroza, C., Levin, H.S., Brown S.A. & Brundage, S.I. (2005). Lost productive work time after mild to moderate traumatic brain injury with and without hospitalization. *Neurosurgery*, 56, 994-1003.

Boake, C., Millis, S.R., High, W.M. Jr. Delmonico, R.L., Kreutzer, J.S., Rosenthal, M., Sherer, M. & Ivanhoe, C.B. (2001). Using early neuropsychologic testing to predict long-term productivity outcome from traumatic brain injury. *Archives of Physical Medicine and Rehabilitation*, 82, 761-768.

Bohnen, N., Van Zutphen, W., Twijnstra, A., Wijnen, G.,Bongers, J. & Jolles, J. (1994). Late outcome of mild head injury: results from a controlled postal survey. *Brain Injury*, 8(8), 701-708.

Borg, J., Holm, L., Peloso, P.M., Cassidy, J.D., Carroll, L.J., von Holst, H., Paniak, C. & Yates, D. (2004). Non-surgical intervention and cost for mild traumatic brain injury: Results of the WHO collaborating centre task force on mild traumatic brain injury. *Journal of Rehabilitation Medicine*, Suppl 43, 76-83.

Borgaro, S.R., Prigatano, G.P., Kwasnica, C. & Rexer, J.L. (2003). Cognitive and affective sequelae in complicated and uncomplicated mild traumatic brain injury. *Brain Injury*, 17(3), 189-198.

Breaugh, J.A. (2003). Effect size estimation: factors to consider and mistakes to avoid. *Journal of Management*, 29(1), 79-97.

Brooks, J., Fos, L.A., Greve, K.W. & Hammond, J.S. (1999). Assessment of executive function in patients with mild traumatic brain injury. *The Journal of Trauma: Injury, Infection, and Critical Care,* 46(1), 159-163.

Brown, A.W., Malec, J.F., McClelland, R.L., Diehl, N.N., Englander, J. & Cifu, D.X. (2005). Clinical elements that predict outcome after traumatic brain injury: a prospective multicenter recursive partitioning (decision-tree) analysis. *Journal of Neurotrauma*, 22(10), 1040-1051.

Bruns, J., Jr. & Hauser, W.A. (2003). The epidemiology of traumatic brain injury: a review. *Epilepsia*, 44(Suppl. 10), 2-10.

Bryant, R.A. (2011). Mental disorders and traumatic injury. *Depression and Anxiety*, 28, 99-102.

Bryant, R.A. (2001). Posttraumatic stress disorder and traumatic brain injury: can they co-exist? *Clinical Psychology Review*, 21(6), 931-948.

Bryant, R. A. (1996). Posttraumatic stress disorder, flashbacks, and pseudomemories in closed head injury. *Journal of Traumatic Stress*, 9, 621–629.

Bryant, R. A. & Harvey, A.G. (1999). Postconcussive symptoms and posttraumatic stress disorder after mild traumatic brain injury. *Journal of Nervous and Mental Disease*, 187(5), 302-305.

Bryant, R.A., Marosszeky, J.E., Crooks, J., Baguley, I.J. & Gurka, J.A. (2007). Interaction of posttraumatic stress disorder and chronic pain following traumatic brain injury. *Journal of Head Trauma and Rehabilitation*, 14(6), 588-594.

Bryant, R.A., O'Donnell, M.L., Creamer, M., McFarlane, A.C., Clark, C.R. & Silove, D. (2010). The psychiatric sequelae of traumatic injury. *American Journal of Psychiatry*, 167, 312-320.

Buckwalter, J.G., Stanczyk, F.Z., McCleary, C.A., Bluestein, B.W., Buckwalter, D.K., Rankin, K.P., Chang, L. & Goodwin, T.M. (1998). Pregnancy, the postpartum, and steroid hormones: effects on cognition and mood. *Psychoneuroendocrinology*, 24(1), 69-84.

Busch, C.R. & Alpern, R.P. (1998). Depression after mild traumatic brain injury: a review of current research. *Neuropsychology Review*, 8(2), 95-108.

Carroll, L.J., Cassidy, J.D., Holm, L., Kraus, J., Coronado, V.G. (2004). Methodological issues and research recommendations for mild traumatic brain injury: The WHO collaborating centre task force on mild traumatic brain injury. *Journal of Rehabilitation Medicine*, Suppl. 43, 113-125.

Carroll, L.J., Cassidy, J.D., Peloso, P.M., Borg, J., von Holst, H., Holm, L., Paniak, C. & Pepin, M. (2004). Prognosis for mild traumatic brain injury: results of the WHO collaborating centre task force on mild traumatic brain injury. *Journal of Rehabilitation Medicine*, Suppl. 43, 84-105.

Casey, P., Huntsdale, C., Angus, G. & Janes, C. Memory in pregnancy. II: Implicit, incidental, explicit, semantic, short-term, working and prospective memory in primigravid, multigravid and postpartum women. *Journal of Psychosomatic Obstetrics & Gynacology*, 20 (3), 158-164.

Cassidy, J.D., Carroll, L.J., Peloso, P.M., Borg, J., von Holst, H., Holm, L., Kraus, J. & Coronado, V.G. (2004). Incidence, risk factors and prevention of mild traumatic brain injury: results of the WHO collaborating centre task force on mild traumatic brain injury. *Journal of Rehabilitation Medicine*, Suppl. 43, 28-60.

Cicerone, K.D. (1996). Attention deficits and dual task demands after mild traumatic brain injury. *Brain Injury*, 10(2), 79-86.

Cifu, D.X., Keyser-Marcus, L., Lopez, E., Wehman, P., Kreutzer, J.S., Englander, J. & High, W. (1997). Acute predictors of successful return to work 1 year after traumatic brain injury: a multicenter analysis. *Archives of Physical medicine and Rehabilitation*, 78, 125-31.

Cohen, J., Cohen, P., West, S.G. & Aiken, L.S. (2003). *Applied multiple regression/correlation analysis for the behavioural sciences*. Mahwah, New Jersey: Lawrence Erlbaum Associates, Inc.

Cortez, S.C., McIntosh, T.K., Noble, L.J. (1989). Experimental fluid percussion brain injury: vascular disruption and neuronal and glial alterations. *Brain Research*, 482, 271-282.

Crepeau, F. & Scherzer, P. (1993). Predictors and indicators of work status after traumatic brain injury: a meta-analysis. *Neuropsychological Rehabilitation*, 3(1), 5-35.

Crosson, B., Novack, T.A., Trenerry, M.R. & Craig, P.L. (1988). California verbal learning test (CVLT) performance inn severely head-injured and neurologically normal adult males. *Journal of Clinical and Experimental Neuropsychology*, 10(6), 754-769.

Cunningham, K., Wolbert, R. & Brockmeier, M.B. (2000). Moving beyond the illness: factors contributing to gaining and maintaining employment. *American Journal of Community Psychology*, 28(4), 481-494.

D'Ambrosio, R., Maris, D.O., Grady, M.S., Winn, H.R. & Janigro, D. (1998). Selective loss of hippocampal long-term potentiation, but not depression, following fluid percussion injury. *Brain Research,* 786, 64–79.

Dawson, D.R., Levine, B., Schwartz, M.L. & Stuss, D.T. (2004). Acute predictors of real-world outcomes following traumatic brain injury: a prospective study. *Brain Injury*, 18(3), 221-238.

de Groot, R.H.M., Hornstra, G., Roozendaal, N. & Jolles, J. (2003). Memory performance, but not information processing speed, may be reduced during early pregnancy. *Journal of Clinical and Experimental Neuropsychology*, 25(4), 482-488.

de Groot, R.H.M., Vuurman, E.F.P.M., Hornstra, G. & Jolles, J. (2006). Differences in cognitive performance during pregnancy and early motherhood. *Psychological Medicine*, 36(7), 1023-1032.

DeLuca, J., Schultheis, M.T., Madigan, N.K., Christodoulou, C. & Averill, A. (2000). Acquisition versus retrieval deficits in traumatic brain injury: implications for memory rehabilitation. *Archives of Physical Medicine and Rehabilitation*, 81, 1327-1333.

Dhandapani, S.S., Gupta, A., Vivekanandhan, S., Sharma, B.S. & Mahapatra, A.K. (2008). Randomized controlled trial of magnesium sulphate in severe closed traumatic brain injury. *Indian Journal of Neurotrauma*, 5(1), 27-33.

Dickerson, F.B., Boronow, J.J., Stallings, C.R., Origoni, A.E., Cole, S. & Yolken, R.H. (2004). Association between cognitive functioning and employment status of persons with bipolar disorder. *Psychiatric Services*, 55(1), 54-58.

Dielman, T.E. (2001). Applied logistic regression for business and economics. 3rd Edition. Pacific Grove, CA: Duxbury.

Dikmen, S., Machamer, J. & Temkin, N. (2001). Mild head injury: facts and artifacts. *Journal of Clinical and Experimental Neuropsychology*, 23(6), 729-738.

Drake, A.I., Gray, N., Yoder, S., Pramuka, M. & Llewellyn, M. (2000). Factors predicting return to work following mild traumatic brain injury: a discriminate analysis. *Journal of Head Trauma and Rehabilitation*, 15(5), 1103-1112.

Dunn, J.T., Lees-Haley, P.R., Brown, R.S., Williams, C.W. & English, L.T. (1995). Neurotoxic complaint base rates of personal injury claimants: implications for neuropsychological assessment. *Journal of Clinical Psychology*, 51(4), 577-584.

Durvasula, R.S., Miller, E.N., Myers, H.M., Satz, P. & Wyatt, G. (1998).Neuropsychological performance and HIV-1 in ethnic minority samples of women and men: Serostatus effects, comparative data, and methodological considerations. *Paper presented at the Annual Meeting of the International Neuropsychological Society*, Honolulu, HI.

Echemendia, R.J., Putukian, M., Mackin, S., Julian, L. & Shoss, N. (2001). Neuropsychological test performance prior to and following sports-related mild traumatic brain injury. *Clinical Journal of Sport Medicine*, 11, 23-31.

Emanuelson, I., Holmkvist, E.A., Bjorklund, R. & Stalhammer, D. (2003). Quality of life and post-concussion symptoms in adults after mild traumatic brain injury: a population-based study in western Sweden. *Acta Neurologica Scandinavica*, 108, 332-338.

Englander, J., Hall, K., Stimpson, T. & Chaffin, S. (1992). Mild traumatic brain injury in an insured population: subjective complaints and return to employment. *Brain Injury*, 6(2), 161-166.

Ergh, T.C., Rapport, L.J., Coleman, R.D. & Hanks, R.A. (2002). Predictors of caregiver and family functioning following traumatic brain injury: social support moderates caregiver distress. *Journal of Head Trauma Rehabilitation*, 17(2), 155-174.

Faul, M., Xu, L., Wald, M.M. & Coronado, V.G. (2010). Traumatic brain injury in the United States: emergency department visits, hospitalisations and deaths 2002-2006. Atlanta (GA): *Centers for Disease Control and Prevention, National Center for Injury Prevention and Control.*

Fawcett, T. (2006). An introduction to ROC analysis. *Pattern Recognition Letters*, 27 (8), 861-874.

Feinstein, A., Hershkop, S., Jardine, A. & Ouchterlony, D. (2000). The prevalence and neuropsychiatric correlates of posttraumatic stress symptoms following mild traumatic brain injury. *Brain and Cognition*, 44, 78-82.

Fife, D. (1987). Head injury with and without hospital admission: comparisons of incidence and short-term disability. *American Journal of Public Health*, 77, 810-812.

Fineman, I., Hovda, D.A., Smith, M., Yoshino, A. & Becker, D.P. (1993). Concussive brain injury is associated with a prolonged accumulation of calcium: a 45Ca autoradiographic study. *Brain Research*, 624, 94-102.

Flaro, L., Green, P. & Robertson, E. (2007). Word memory test failure 23 times higher in mild brain injury than in parents seeking custody: the power of external incentives. *Brain Injury*, 21(4), 373-383.

Fleming, J., Tooth, L., Hassell, M. & Chan, W. (1999). Prediction of community integration and vocational outcome 2-5 years after traumatic brain injury in Australia. *Brain Injury*, 13(6), 417-431.

Frencham, K.A.R., Fox, A.M. & Maybery, M.T. (2005). Neuropsychological studies of mild traumatic brain injury: a meta-analytic review of research since 1995. *Journal of Clinical and Experimental Neuropsychology*, 27, 334-351.

Friedland, J.F. & Dawson, D.R. (2001). Function after motor vehicle accidents: a prospective study of mild head injury and posttraumatic stress. *Journal of Nervous and Mental Disease*, 189, 426-434.

Gardiner M., Smith, M.L., Kagstrom, E., Shohami, E. & Siesjo, B.K. (1982). Influence of blood glucose concentration on brain lactate accumulation during severe hypoxia and subsequent recovery of brain energy metabolism. *Journal of Cerebral Blood Flow Metabolism,* 2, 429–438.

Gardner, A., Shores, E.A. & Batchelor, J. (2010). Reduced processing speed in rugby union players reporting three or more previous concussions. Archives of Clinical Neuropsychology, 25, 174-181.

Gardner, A., Shores, E.A., Batchelor, J. & Honan, C, A. (2012). Diagnostic efficiency of ImPACT and CogSport in concussed rugby union players who have not undergone baseline neurocognitive testing. Applied Neuropsychology: Adult, 19, 90-97.

Gervais, R., Green, P., Russell, A.S., Pieschl, S. & Allen III, L.M. (2000). Failure on symptom validity tests associated with disability incentives in fibromyalgia patients. *Archives of Clinical Neuropsychology*, 15, 841-842.

Giza, C.C. & Hovda, D.A. (2001). The neurometabolic cascade of concussion. *Journal of Athletic Training*, 36(3), 228-235.

Goranson, T.E., Graves, R.E., Allison, D. & La Freniere, R. (2003). Community integration following multidisciplinary rehabilitation for traumatic brain injury. *Brain Injury*, 17(9), 759-774.

Gorman, J.M. (1996/1997). Comorbid depression and anxiety spectrum disorders. *Depression and Anxiety*, 4, 160-168.

Gouvier, W.D., Cubic, B., Jones, G., Brantley, P. & Cutlip, Q. (1992). Postconcussion symptoms and daily stress in normal and head-injured college populations. *Archives of Clinical Neuropsychology*, 7, 193-211.

Green, P., Allen, L.M., & Astner, K. (1996). The Word Memory Test: A user's guide to the oral and computerized-administered forms. Durham, NC: CogniSyst.

Green, P., Flaro, L. & Courtney, J. (2009). Examining false positives on the word memory test in adults with mild traumatic brain injury. *Brain Injury*, 23(9), 741-750.

Green, P. & Iverson, G.L. (2001). Validation of the Computerised Assessment of Response Bias in litigating patients with head injuries. *The Clinical Neuropsychologist*, 15(4), 492-497.

Green, P., Iverson, G.L. & Allen, L. (1999). Detecting malingering in head injury litigation with the word memory test. *Brain Injury*, 13(10), 813-819.

Green, P., Rohling, M.L., Lees-Haley, P.R. & Allen, L.M. (2001). Effort has a greater effect on test scores than severe brain injury in compensation claimants. *Brain Injury*, 15(12), 1045-1060.

Green, R.E.A., Melo, B., Christensen, B., Ngo, L., Monette, G. & Bradbury, C. (2008). Measuring premorbid IQ in traumatic brain injury: an examination of the validity of the

Wechsler Test of Adult Reading (WTAR). *Journal of Clinical and Experimental Neuropsychology*, 30(2), 163-172.

Grigsby, J., Rosenberg, N.L. & Busenbark, D. (1995). Chronic pain is associated with deficits in information processing. *Perceptual and Motor Skills*, 81, 403-410.

Gronwall, D. & Wrightson, P. (1980). Duration of post-traumatic amnesia after mild head injury. *Journal of Clinical Neuropsychology*, 2(1), 51-60.

Guerin, F., Kennepohl, S., Leveille, G., Dominique, A. & McKerral, M. (2006). Vocational outcome indicators in atypically recovering mild TBI: a post-intervention study. *NeuroRehabilitation*, 21, 295-303.

Guskiewicz, K.M. & Mihalik, J.P (2011). Biomechanics of sport concussion: quest for the elusive injury threshold. *Exercise and Sport Sciences Reviews*, 39(1), 4-11.

Hanlon, R.E., Demery, J.A., Martinovich, Z. & Kelly, J.P. (1999). Effects of acute injury characteristics on neuropsychological status and vocational outcome following mild traumatic brain injury. *Brain Injury*, 13(11), 873-887.

Hart, R.P., Martelli, M.F. & Zasler, N.D. (2000). Chronic pain and neuropsychological functioning. *Neuropsychology Review*, 10(3), 131-149.

Hartman, D.E. (2002). The unexamined lie is a lie worth fibbing. Neuropsychological malingering and the Word Memory Test. *Archives of Clinical Neuropsychology*, 17, 709-714.

Harvey, A.G. & Bryant, R.A. (2000). Two-year prospective evaluation of the relationship between acute stress disorder and posttraumatic stress disorder following mild traumatic brain injury. *The American Journal of Psychiatry*, 157, 626-628.

Harvey, A. G. & Bryant, R. A. (2001). Reconstructing trauma memories: a prospective study of ‘‘amnesic’’ trauma survivors. *Journal of Traumatic Stress*, 14(2), 277- 282.

Helps, Y., Henley, G. & Harrison, J. (2008). Hospital separations due to traumatic brain injury, Australia 2004-05. *Australian Institute of Health and Welfare Injury Research and Statistics Series*, Number 45.

Henry, J.D. & Rendell, P.G. (2007). A review of the impact of pregnancy on memory function. *Journal of Clinical and Experimental Neuropsychology*, 29(8), 793-803.

Hickling, E.J., Gillen, R., Blanchard, E., Buckley, T. & Taylor, A. (1998). Traumatic brain injury and posttraumatic stress disorder: a preliminary investigation of neuropsychological test results in PTSD secondary to motor vehicle accidents. *Brain Injury*, 12(4), 265-274.

Hoare, P.N. & Machin, M.A. (2010). The impact of reemployment on access to the latent and manifest benefits of employment and mental health. *Journal of Occupational and Organizational Psychology*, 83, 759-770.

Hoffman, J.M., Pagulayan, K.F., Zawaideh, N., Dikmen, S., Temkin, N. & Bell, K.R. (2007). Understanding pain after traumatic brain injury. Impact on community participation. *American Journal of Physical Medicine & Rehabilitation*, 86(12), 962-969.

Hoge, C.W., McGurk, D., Thomas, J.L., Cox, A.L., Engel, C.C. & Castro, C.A. (2008). Mild traumatic brain injury in U.S. soldiers returning from Iraq. *The New England Journal of Medicine*, 358(5), 453-463.

Hosmer, D.W. & Lemeshow, S. (2000). *Applied logistic regression*. 2nd Edition. Hoboken, New Jersey: John Wiley & Sons Inc.

Howell, D.C. (2002). *Statistical methods for psychology*, 5th Edition. Pacific Grove, CA: Wadsworth Group.

Iverson, G.L. (2006). Ethical issues associated with the assessment of exaggeration, poor effort, and malingering. *Applied Neuropsychology*, 13(2), 77-90.

Iverson, G.L. & Lange, R.T. (2003). Examination of “postconcussion-like” symptoms in a healthy sample. *Applied Neuropsychology*, 10(3), 137-144.

Iverson, G.L., Lange, R.T., Gaetz, M. & Zasler, N.D. (2007). Mild TBI. In Zasler, N.D., Katz, D.I. & Zafonte, R.D. (Eds), *Brain Injury Medicine. Principles and Practices* (pp 333-371). New York, Demos Medical Publishing.

Iverson, G.L., Lovell, M.R. & Smith, S.S. (2000). Does brief loss of consciousness affect cognitive functioning after mild head injury? *Archives of Clinical Neuropsychology*, 15(7), 643-648.

Iverson, G.L. & McCracken, L.M. (1997). 'Postconcussive' symptoms in persons with chronic pain. *Brain Injury*, 11(11), 783-790.

Jahoda, M. (1982). *Employment and unemployment: A social-psychological analysis*. Cambridge, England: Cambridge University Press.

Jenson, M.P. & Karoly P. (2011). Self-report procedures for assessing pain in adults. In: Turk, D.C., Melzack, R. eds. Handbook of pain assessment in adults, 2nd edn. New York: Guildford Press, 19-44.

Ji, G., Sun, H., Fu, Y., Li, Z., Pais-Vieira, M., Galhardo, V. & Neugebauer, V. (2010). Cognitive impairment in pain through amygdale-driven prefrontal cortical deactivation. *The Journal of Neuroscience*, 30(15), 5451-5464.

Johnstone, B., Mount, D. & Schopp, L.H. (2003). Financial and vocational outcomes 1 year after traumatic brain injury. *Archives of Physical and Medical Rehabilitation*, 84, 238-241.

Kalimo, H., Rehncrona, S., Soderfeldt, B., Olsson, Y. & Siesjo, B.K. (1981). Brain lactic acidosis and ischemic cell damage, 2: histopathology. *Journal of Cerebral Blood Flow Metabolism,* 1, 313–327.

Kashluba, S., Hanks, R.A., Casey, J.E. & Millis, S.R. (2008). Neuropsychologic and functional outcome after complicated mild traumatic brain injury. *Archives of Physical Medicine and Rehabilitation*, 89, 904-911.

Kessler, R.C., Berglund, P., Demler, O., Jin, R., Merikangas, K.R. & Walters, E.E. (2005). Lifetime prevalence and age-of-onset distributions of DSM-IV disorders in the national comorbidity survey replication. *Archives of General Psychiatry*, 62, 593-602.

Keyser-Marcus, L.A., Bricout, J.C., Wehman, P., Campbell, L.R., Cifu, D.X., Englander, J., High, W. & Zafonte, R.D. (2002). Acute predictors of return to employment after traumatic brain injury: a longitudinal follow-up. *Archives of Physical Medicine and Rehabilitation*, 83, 635-641.

King, N.S. (1996). Emotional, neuropsychological, and organic factors: their use in the prediction of persisting postconcussion symptoms after moderate and mild head injuries. *Journal of Neurology, Neurosurgery, and Psychiatry*, 61, 75-81.

King, N.S. (1997). Post-traumatic stress disorder and head injury as a dual diagnosis: 'islands' of memory as a mechanism. *Journal of Neurology, Neurosurgery, and Psychiatry*, 62, 82–84.

Kinicki, A.J., Prissia, G.E. & McKee-Ryan, F.M. (2000). A panel study of coping with involuntary job loss. *Academy of Management Journal*, 43(1), 90-100.

Kolakowsky-Hayner, S.A. & Kreutzer, J.S. (2001). Return to work after brain injury: a self-directed approach. *NeuroRehabilitation*, 16, 41-47.

Koponen, S., Taiminen, T., Portin, R., Himanen, L., Isoniemi, H., Heinonen, H., Hinkka, S. & Tenovuo, O. (2002). Axis I and II psychiatric disorders after traumatic brain injury: a 30 year follow-up study. *The American Journal of Psychiatry*, 159, 1315-1321.

Kraus, J.F., Fife, D., Ramstein, K., Conroy, C. & Cox, P. (1986). The relationship of family income to the incidence, external causes, and outcomes of serious brain injury, San Diego county, California. *American Journal of Public Health*, 76, 1345-1347.

Kuhajda, M.C., Thorn, B.E., & Klinger, M.R. (1998).The effect of pain on memory for affective words. *Annals of Behavioral Medicine*, 20(1), 31-35.

Kuhajda, M.C., Thorn, B.E., Klinger, M.R. & Rubin, N.J. (2002). The effect of headache pain on attention (encoding) and memory (recognition). *Pain*, 97, 213-221.

Landre, N., Poppe, C.J., Davis, N., Schmaus, B. & Hobbs, S.E. (2006). Cognitive functioning and postconcussive symptoms in trauma patients with and without mild TBI. *Archives of Clinical Neuropsychology*, 21, 255-273.

Lange, R.T., Iverson, G.L. & Franzen, M.D. (2009). Neuropsychological functioning following complicated vs. uncomplicated mild traumatic brain injury. *Brain Injury*, 23(2), 83-91.

Lange, R.T., Iverson, G.L. & Rose, A. (2010). Depression strongly influences postconcussion symptom reporting following mild traumatic brain injury. Journal of Head Trauma Rehabilitation, 26(2), 127-137.

Lees-Haley, P.R., Willaims, C.W., Zasler, N.D., Marguilies, S., English, L.T. & Stevens, K.B. (1997). Response bias in plaintiffs' histories. *Brain Injury*, 11(11), 791-799.

Levin, H.S., Brown, S.A., Song, J.X., McCauley, S.R., Boake, C., Contant, C.F., Goodman, H. & Kotrla, K.J. (2001). Depression and posttraumatic stress disorder at three months after mild to moderate traumatic brain injury. *Journal of Clinical and Experimental Neuropsychology*, 23(6), 754-769.

Levin, H.S., McCauley, S.R., Pedroza Josic, C., Boake C., Brown, S.A., Goodman, H.S., Merritt, S.G. & Brundage, S.I. (2005). Predicting depression following mild traumatic brain injury. *Archives of General Psychiatry*, 62, 523-528.

Machamer, J., Temkin, N., Fraser, R., Doctor, J.N. & Dikmen, S. (2005). Stability of employment after traumatic brain injury. *Journal of the International Neuropsychological Society*, 11, 807-816.

Martelli, M.F., Grayson, R.L. & Zasler, N.D. (1999). Posttraumatic headache: neuropsychological and psychological effects and treatment implications. *Journal of Head Trauma Rehabilitation*, 14(1), 49-69.

Martelli, M.F., Nicholson, K. & Zasler, N.D. (2007). Psychological approaches to comprehensive pain assessment and management following TBI. In *Brain injury medicine: principles and practice* (pp. 723-742). New York, New York: Demos Medical Publishing.

Marzban, C. (2004). The ROC curve and the area under it as performance measures. *Weather and Forecasting*, 19, 1106-1114.

Mathias, J.L., Beall, J.A. & Bigler, E.D. (2004). Neuropsychological and information processing deficits following mild traumatic brain injury. *Journal of the International Neuropsychological Society*, 10, 286-297.

Mathias, J.L., Bowden, S.C. & Barrett-Woodbridge, M. (2007). Accuracy of the Wechsler Test of Adult Reading (WTAR) and National Adult Reading Test (NART) when estimating IQ in a healthy Australian sample. *Australian Psychologist*, 42(1), 49-56.

Mathias, J.L., Bowden, S.C., Bigler, E.D. & Rosenfeld, J.V. (2007). Is performance on the Wechsler test of adult reading affected by traumatic brain injury? *British Journal of Clinical Psychology*, 46, 457-466.

Mayou, R., Bryant, B. & Duthie, R. (1993). Psychiatric consequences of road traffic accidents. *British Medical Journal*, 307, 647–651.

McAuley, D. Opioid (narcotic) analgesic converter. http://www.globalrph.com/narcotic.cgi.

McCauley, S.R., Boake, C., Levin, H.S., Contant, C.F. and Song, J.X. (2001). Postconcussal disorder following mild to moderate traumatic brain injury: anxiety, depression, and social support as risk factors and comorbidities. *Journal of Clinical and Experimental Neuropsychology*, 23(6), 792-808.

McCauley, S.R., Boake, C., Pedroza, C., Brown, S.A., Levin, H.S., Goodman, H.S. & Merritt, S.G. (2005). Postconcussional disorder. Are the DSM-IV criteria an improvement over the ICD-10? *The Journal of Nervous and Mental Disease*, 193(8), 540-550.

McCrea, M.A. (2008). *Mild traumatic brain injury and postconcussion syndrome. The new evidence base for diagnosis and treatment.* New York: Oxford University Press

McCrea, M., Iverson, G.L., McAllister, T.W., Hammeke, T.A., Powell, M.R., Barr, W.B. & Kelly, J.P. (2009). An integrated review of recovery after mild traumatic brain injury (MTBI): implications for clinical management. *The Clinical Neuropsychologist*, 23, 1368-1390.

McCrory, P.R., Ariens, M. & Berkovic, S.F. (2000). The nature and duration of acute concussive symptoms in Australian football. *Clinical Journal of Sport Medicine*, 10, 235-238.

McDowall, J. & Moriarty, R. (2000). Implicit and explicit memory in pregnant women: an analysis of data-driven and conceptually driven processes. *The Quarterly Journal of Experimental Psychology*, 53A(3), 729-740.

McGurk, S.R., Mueser, K.T., Harvey, P.D., LaPuglia, R. & Marder, J. (2003). Cognitive and symptom predictors of work outcomes for clients with schizophrenia in supported employment. *Psychiatric Services*, 54(8), 1129-1135.

McIntosh, T.K. (1993). Novel pharmacologic therapies in the treatment of experimental traumatic brain injury: a review. *Journal of Neurotrauma*, 10, 215-261.

McKee-Ryan, F.M., Song, Z., Wanberg, C.R. & Kinicki, A.J. (2005). Psychological and physical well-being during unemployment. *Journal of Applied Psychology*, 90(1), 53-76.

McLaughlin, M. (1995). Employability Skills Profile: what are employers looking for? ERIC Digest. *ERIC Clearinghouse on Counselling and Student Services Greensboro NC., Canadian Guidance and Counselling Foundation Ottawa (Ontario).*

Meares, S., Shores, E.A., Batchelor, J., Baguley, I.J., Chapman, J., Gurka, J. & Marosszeky, J.E. (2006). The relationship of psychological and cognitive factors and opioids in the development of the postconcussion syndrome in general trauma patients with mild traumatic brain injury. *Journal of the International Neuropsychological Society*, 12, 792-801.

Meares, S., Shores, E.A., Taylor, A.J., Batchelor, J., Bryant, R.A., Baguley, I.J., Chapman, J., Gurka, J., Dawson, K., Capon, L. & Marosszeky, J.E. (2008). Mild traumatic brain injury does not predict acute postconcussion syndrome. *Journal of Neurology, Neurosurgery and Psychiatry*, 79, 300-306.

Meares, S., Shores, E.A., Taylor, A.J., Batchelor, J., Bryant, R.A., Baguley, I.J., Chapman, J., Gurka, J. & Marosszeky, J.E. (2011). The prospective course of postconcussion syndrome: the role of mild traumatic brain injury. *Neuropsychology*, 25(4), 454-465.

Meares, S., Shores, E.A., Taylor, A.J., Lammél, A. & Batchelor, J. (2011). Validation of the Abbreviated Westmead Post-traumatic Amnesia Scale: a brief measure to identify acute cognitive impairment in patients with mild traumatic brain injury. *Brain Injury*, 25(12), 1198-1205.

Metz, C.E. (1978). Basic principles of ROC analysis. *Seminars in Nuclear Medicine*, 8(4), 283-298.

Meythaler, J.M., Zafonte, R.D., Lombard, L. & Reddy, C.C. (2007). Neuropharmacology: a rehabilitation perspective. In Zasler, N.D., Katz, D.I. & Zafonte, R.D. (Eds), *Brain Injury Medicine. Principles and Practices* (pp 1023-1036). New York, Demos Medical Publishing.

Miller, E.N. (1990). California Computerized Assessment Package (CalCAP) manual. Los Angeles: Norland Software.

Miller, E.N. (1995). Cognitive testing using reaction time and traditional neuropsychological procedures. *Journal of the International Neuropsychological Society*, 1, 393.

Miller, L. (2001). Not just malingering: syndrome diagnosis in traumatic brain injury litigation. *NeuroRehabilitation*, 16, 109-122.

Miller, L.J. & Donders, J. (2001).Subjective symptomatology after traumatic head injury. *Brain Injury*, 15(4), 297-304.

Moher, D., Liberati, A., Tetzlaff, J., Altman, D.G. & The PRISMA Group (2009). Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. *PLoS Medicine*, 6(7), 1-28.

Mooney, G., Speed, J. & Sheppard, S. (2005). Factors related to recovery after mild traumatic brain injury. *Brain Injury*, 19(12), 975-987.

Moore, E.L., Terryberry-Spohr, L. & Hope, D.A. (2006). Mild traumatic brain injury and anxiety sequelae: a review of the literature. *Brain Injury*, 20(2), 117-132.

Murphy, G.C. & Athanasou, J.A. (1999). The effect of unemployment on mental health. *Journal of Occupational and Organizational Psychology*, 72, 83-99.

Nampiaparampil, D.E. (2008). Prevalence of chronic pain after traumatic brain injury. *Journal of the American Medical Association*, 300(6), 711-719.

National Institute of Neurological Disorders and Stroke. Traumatic Brain injury Information page (available at http://www.ninds.nih.gov/disorders/tbi/tbi.htm).Accessed on 31/07/2010.

Nightingale, E.J., Soo, C.A. & Tate, R.L. (2007). A systematic review of early prognostic factors for return to work after traumatic brain injury. *Brain Impairment*, 8(2), 101-142.

Nolin, P. & Heroux, L. (2006). Relations among sociodemographic, neurologic, clinical, and neuropsychologic variables, and vocational status following mild traumatic brain injury. A follow-up study. *Journal of Head Trauma and Rehabilitation*, 21(6), 514-526.

Norton, P.J. & Asmundson, G.J.G. (2004). Anxiety sensitivity, fear, and avoidance behaviour in headache pain. *Pain*, 111, 218-223.

O'Connell, M.J. (2000). Prediction of return to work following traumatic brain injury: intellectual, memory, and demographic variables. *Rehabilitation Psychology*, 45(2), 212-217.

Ommaya, A.K. & Gennarelli, T.A. (1974). Cerebral concussion and traumatic unconsciousness. Correlation of experimental and clinical observations on blunt head injuries. *Brain*, 97(1), 633-654.

O'Neill, J., Hibbard, M.R., Brown, M., Jaffe, M., Sliwinski, M.,V. Fandergoot, D. & Weiss, M.J. (1998).The effect of employment on quality of life and community integration after traumatic brain injury. *Journal of Head Trauma Rehabilitation*, 13(4), 68-79.

Ono, K. & Kanno, M. (1996). Influences of the physical parameters on the risk to neck injuries in low impact speed rear-end collisions. *Accident Analysis and Prevention*, 28(4), 493-499.

Osteen, C.L., Moore, A.H., Prins, M.L. & Hovda, D.A. (2001). Age-dependency of [45] calcium accumulation following lateral fluid percussion: acute and delayed patterns. *Journal of Neurotrauma*, 18, 141-162.

Ownsworth, T., Fleming, J.M. & Hardwick, S. (2006). Symptom reporting and associations with compensation status, self-awareness, causal attributions and emotional wellbeing following traumatic brain injury. *Brain Impairment*, 7(2), 95-106.

Ownsworth, T. & McKenna, K. (2004). Investigation of factors related to employment outcome following traumatic brain injury: a critical review and conceptual model. *Disability and Rehabilitation*, 26(13), 765-784.

Paniak, C., Reynolds, S., Toller-Lobe, G., Melnyk, A., Nagy, J. & Schmidt, D. (2002). A longitudinal study of the relationship between financial compensation and symptoms after treated mild traumatic brain injury. *Journal of Clinical and Experimental Neuropsychology*, 24(2), 187-193.

Paniak, C., Toller-Lobe, G., Durand, A. & Nagy, J. (1998). A randomized trial of two treatments for mild traumatic brain injury. *Brain Injury*, 12(12), 1011-1023.

Paniak, C., Toller-Lobe, G., Melnyk, A. & Nagy, J. (2000). Prediction of vocational status three to four months after treated mild traumatic brain injury. *Journal of Musculoskeletal Pain*, 8(1/2), 193-200.

Panopalis, P., Julian, L., Yazdany, J., Gillis, J.Z., Trupin, L., Hersh, A., Criswell, L.A., Katz, P. & Yelin, E. (2007). Impact of memory impairment on employment status in persons with systemic lupus erythematosus. *Arthritis Care & Research*, 57(8), 1453-1460.

Paul, K.I. & Batinic, B. (2010). The need for work: Jahoda's latent functions of employment in a representative sample of the German population. *Journal of Organizational Behavior*, 31, 45-64.

Pellman, E.J., Viano, D.C., Tucker, A.M., Casson, I.R. & Waeckerle, J.F. (2003). Concussion in professional football: reconstruction of game impacts and injuries. Neurosurgery, 53(4), 799-814.

Pengel, L.H.M., Herbert, R.D., Maher, C.G. & Refshauge, K.M. (2003). Acute low back pain: systematic review of its prognosis. *British Medical Journal*, 327, 323-327.

Ponsford, J., Facem, P.C., Willmott, C., Rothwell, A., Kelly, A., Nelms, R. & Ng, K. (2004). Use of the Westmead PTA scale to monitor recovery of memory after mild head injury. *Brain Injury*, 18(6), 603-614.

Ponsford, J. & Kinsella, G. (1992). Attentional deficits following closed-head injury. *Journal of Clinical and Experimental Neuropsychology*, 14(5), 822-838.

Ponsford, J., Willmott, C., Rothwell, A., Cameron, P., Kelly, A., Nelms, R., Curran, C. & Ng, K. (2000). Factors influencing outcome following mild traumatic brain injury in adults. *Journal of the International Neuropsychological Society*, 6, 568-579.

Raskin, S.A., Mateer, C.A. & Tweeten, R. (1998). Neuropsychological assessment of individuals with mild traumatic brain injury. *The Clinical Neuropsychologist*, 12(1), 21-30.

Reynolds, S., Paniak, C., Toller-Lobe, G. & Nagy, J. (2003). A longitudinal study of compensation-seeking and return to work in a treated mild traumatic brain injury sample. *Journal of Head Trauma Rehabilitation*, 18(2), 139-147.

Rimel, R.W., Giordani, B., Barth, J.T., Boll, T.J. & Jane, J.A. (1981). Disability caused by minor head injury. *Neurosurgery*, 9(3), 221-228.

Rosenthal, M., Christensen, B.K. & Ross, T.P. (1998). Depression following traumatic brain injury. *Archives of Physical Medicine and Rehabilitation*, 79, 90-103.

Rudas, T. (1998). *Odds ratios in the analysis of contingency tables*. Thousand Oaks, CA: Sage.

Ruff, R.M. & Jurica, P. (1999). In search of a unified definition for mild traumatic brain injury. *Brain Injury*, 13(12), 943-952.

Ruffolo, C.F., Friedland, J.F., Dawson, D.R., Colantonio, A. & Lindsay, P.H. (1999). Mild traumatic brain injury from motor vehicle accidents: factors associated with return to work. *Archives of Physical Medicine and Rehabilitation*, 80, 392-398.

Ryan, L.M. & Warden, D.L. (2003). Post concussion syndrome. *International Review of Psychiatry*, 15, 310-316.

Sander, A.M., Kreutzer, J.S., Rosenthal, M., Delmonico, R. & Young, M.E. (1996). A multicenter longitudinal investigation of return to work and community integration following traumatic brain injury. *Journal of Head Trauma Rehabilitation*, 11(5), 70-84.

Sanders, M.J., Sick, T.J., Perez-Pinzon, M.A., Dietrich, W.D. & Green, E.J. (2000). Chronic failure in the maintenance of long-term potentiation following fluid percussion injury in the rat. *Brain Research,* 861, 69–76.

Sawchyn, J.M., Brulot, M.M. & Strauss, E. (2000). Note on the use of the postconcussion syndrome checklist. *Archives of Clinical Neuropsychology*, 15(1), 1-8.

Sbordone R.L. & Liter, J.C. (1995). Mild traumatic brain injury does not produce post-traumatic stress disorder. *Brain Injury*, 9, 405–412

Schmand, B., Lindeboom, J., Schagen, S., Heijt, R., Koene, T. & Hamburger, H.L. (1998). Cognitive complaints in patients after whiplash injury: the impact of malingering. *Journal of Neurology, Neurosurgery and Psychiatry*, 64, 339-343.

Schretlen, D.J. & Shapiro, A.M. (2003). A quantitative review of the effects of traumatic brain injury on cognitive functioning. *International Review of Psychiatry*, 15, 341-349.

Seminowicz, D.A. & Davis, K.D. (2007). Pain enhances functional connectivity of a brain network evoked by performance of a cognitive task. *Journal of Neurophysiology*, 97, 3651-3659.

Serlin, R.C., Mendoza, T.R., Nakamura, Y., Edwards, K.R. & Cleeland, C.S. (1995). When is cancer pain mild, moderate or severe? Grading pain severity by its interference with function. *Pain*, 61, 277-284.

Sherer, M., Nick, T.G., Sander, A.M., Hart, T., Hanks, R., Rosenthal, M., High, W.M. Jr., Yablon, S.A. (2003). Race and productivity outcome after traumatic brain injury. Influence of confounding factors. *Journal of Head Trauma Rehabilitation*, 18(5), 408-424.

Sherer, M., Novack, T.A., Sander, A.M., Struchen, M.A., Alderson, A. & Nakase Thompson, R. (2002). Neuropsychological assessment and employment outcome after traumatic brain injury: a review. *The Clinical Neuropsychologist*, 16(2), 157-178.

Shores, E.A.(1995).Further concurrent validity data on the Westmead PTA Scale. *Applied Neuropsychology*, 2, 167-169.

Shores E.A., Lammel, A., Hullick, C., Sheedy, J., Flynn, M., Levick, W. & Batchelor, J. (2008). The diagnostic accuracy of the Revised Westmead PTA Scale as an adjunct to the Glasgow Coma Scale in the early identification of cognitive impairment in patients with mild traumatic brain injury. *Journal of Neurology, Neurosurgery & Psychiatry*, 79, 1100-1106.

Shores EA, Marosszeky JE, Sandanam J, & Batchelor, J. (1986). Preliminary validation of a clinical scale for measuring the duration of post-traumatic amnesia. *Medical Journal of Australia*, 144, 569–572.

Sick, T.J., Perez-Pinzon, M.A. & Feng, Z.Z. (1998). Impaired expression of long-term potentiation in hippocampal slices 4 and 48 h following mild fluid-percussion brain injury in vivo. *Brain Research,* 785, 287–292.

Smith, A. (1982). *Symbol Digit Modalities Test* (manual revised 1982). Los Angeles: Western Psychological Publishers.

Smith-Seemiller, L., Fow, N.R., Kant, R., Franzen, M.D. (2003). Presence of post-concussion symptoms in patients with chronic pain vs mild traumatic brain injury. *Brain Injury*, 17(3), 199-206.

Sosin, D.M., Sniezek, J.E. & Thurman, D.J. (1996). Incidence of mild and moderate brain injury in the United States, 1991. *Brain Injury*, 10(1), 47-54.

Sterr, A., Herron, K.A., Hayward, C. & Montaldi, D. (2006). Are mild head injuries as mild as we think? Neurobehavioral concomitants of chronic post-concussion syndrome. BMC Neurology, 6, 7.

Stevenson, M., Segui-Gomez, M., Lescohier, I., Di Scala, C. & McDonald-Smith, G. (2001). An overview of the injury severity score and the new injury severity score. *Injury Prevention*, 7, 10-13.

Stranjalis, G., Korfias, S., Papapetrou, C., Kouyialis, A., Boviatsis, E., Psachoulia, C. & Sakas, D.E. (2004). Elevated serum S-100B protein as a predictor of failure to short-term return to work or activities after mild head injury. *Journal of Neurotrauma*, 21(8), 1070-1075.

Strauss, E., Sherman, E.M.S. & Spreen, O. (2006). *A compendium of neuropsychological tests: administration, norms and commentary*, 3rd Edition. New York: Oxford University Press.

Stulemeijer, M., Andriessen, T.M.J.C., Brauer, J.M.P., Vos, P.E. & van der Werf, S. (2007). Cognitive performance after mild traumatic brain injury: the impact of poor effort on test results and its relation to distress, personality and litigation. *Brain Injury*, 21(3), 309-318.

Stulemeijer, M., van der Werf, S., Borm, G.F. & Vos, P.E. (2008). Early prediction of favourable recovery 6 months after mild traumatic brain injury. *Journal of Neurology, Neurosurgery and Psychiatry*, 79, 936-942.

Summers, C.R., Ivins, B. & Schwab, K.A. (2009). Traumatic brain injury in the United States: an epidemiologic overview. *Mount Sinai Journal of Medicine*, 76, 105-110.

Tabachnick, B.G. & Fidell, L.S. (2001). *Using multivariate statistics*, 4th ed. Boston: Allyn and Bacon.

Tate, R.L. & Broe, G.A. (1999). Psychosocial adjustment after traumatic brain injury: what are the important variables? *Psychological Medicine*, 29, 713-725.

Tate, R.L., McDonald, S. & Lulham, J.M. (1998). Incidence of hospital-treated traumatic brain injury in an Australian community. *Australian and New Zealand Journal of Public Health*, 22(4), 419-423.

Taylor, A.E., Cox, C.A. & Mailis, A. (1996). Persistent neuropsychological deficits following whiplash: evidence for chronic mild traumatic brain injury? *Archives of Physical Medicine and Rehabilitation*, 77, 529-535.

Teasdale, G.M. (1995). Head Injury. *Journal of Neurology, Neurosurgery and Psychiatry*, 58, 526-539.

Teasdale, G. & Jennett, B. (1974). Assessment of coma and impaired consciousness. A practical scale. *Lancet*, 2, 81-84.

The Psychological Corporation. *Wechsler Test of Adult Reading*. San Antonio, Texas: Harcourt Assessment, 2001.

Trahan, D.E., Ross, C.E. & Trahan, S.L. (2001). Relationships among postconcussional-type symptoms, depression, and anxiety in neurologically normal young adults and victims of mild brain injury. *Archives of Clinical Neuropsychology*, 16, 435-445.

Tsanadis, J., Montoya, E., Hanks, R.A., Millis, S.R., Fichtenberg, N.L. & Axelrod, B.N. (2008). Brain injury severity, litigation status, and self-report of postconcussive symptoms. *The Clinical Neuropsychologist*, 22, 1080-1092.

Unverzagt, F.W., Gao, S., Baiyewu, O., Ogunniyi, A.O., Gureje, O., Perkins, A., Emsley, C.L., Dickens, J., Evans, R., Musick, B., Hall, K.S., Hui, S.L. & Hendrie, H.C. (2001). Prevalence of cognitive impairment. Data from the Indianapolis Study of Health and Aging. *Neurology*, 1655-1662.

Van der Naalt, J. (2001). Prediction of outcome in mild to moderate head injury: a review. *Journal of Clinical and Experimental Neuropsychology*, 23(6), 837-851.

Van der Naalt, J., van Zomeren, A.H., Sluiter, W.J. & Minderhoud, J.M. (1999). One year outcome in mild to moderate head injury: the predictive value of acute injury characteristics related to complaints and return to work. *Journal of Neurology, Neurosurgery and Psychiatry*, 66, 207-213.

Van Velzen, J.M., Van Bennekom, C.A.M., Edelaar, M.J.A., Sluiter, J.K. & Frings-Dresen, M.H.W. (2009a). How many people return to work after acquired brain injury? A systematic review. *Brain Injury*, 23(6), 473-488.

Van Velzen, J.M., Van Bennekom, C.A.M., Edelaar, M.J.A., Sluiter, J.K. & Frings-Dresen, M.H.W. (2009b). Prognostic factors of return to work after acquired brain injury. A systematic review. *Brain Injury*, 23(5), 385-395.

Vanderploeg, R.D., Crowell, T.A. & Curtiss, G. (2001). Verbal learning and memory deficits in traumatic brain injury: encoding, consolidation, and retrieval. *Journal of Clinical and Experimental Neuropsychology*, 23(2), 185-195.

Vanderploeg, R.D., Curtiss, G. & Belanger, H.G. (2005). Long-term neuropsychological outcomes following mild traumatic brain injury. *Journal of the International Neuropsychological Society*, 11, 228-236.

Vanderploeg, R.D., Curtiss, G., Duchnick, J.J. & Luis, C.A. (2003). Demographic, medical, and psychiatric factors in work and marital status after mild head injury. *Journal of Head Trauma and Rehabilitation*, 18(2), 148-163.

Vink, R., Faden, A.I. & McIntosh, T.K. (1988). Changes in cellular bioenergetic state following graded traumatic brain injury in rats: determination by phosphorus 31 magnetic resonance spectroscopy. *Journal of Neurotrauma*, 5(4), 315-330.

Vink, R., McIntosh, T.K., Demediuk, P. & Faden, A.I. (1987). Decrease in total and free magnesium concentration following traumatic brain injury in rats. *Biochemical and Biophysical Research Communications*, 149(2), 594-599.

Voller, B., Benke, T., Benedetto, K., Schnider, P., Auff, E. & Aichner, F. (1999). Neuropsychological, MRI and EEG findings after very mild traumatic brain injury. *Brain Injury*, 13(10), 821-827.

Wang, Y., Chan R.C.K. & Deng, Y. (2006). Examination of post-concussion-like symptoms in healthy university students: relationships to subjective and objective neuropsychological function performance. *Archives of Clinical Neuropsychology*, 21, 339-347.

Waterloo, K., Ingebrigtsen, T. & Romner, B. (1997). Neuropsychological function in patients with increased serum levels of protein S-100 after minor head injury. *ActaNeurochirurgica,* 139, 26-32.

Wehman, P., Targett, P., West, M. & Kregel, J. (2005). Productive work and employment for persons with traumatic brain injury: what have we learned after 20 years? *Journal of Head Trauma Rehabilitation*, 20(2), 115-127.

Wilhelm, K., Mitchell, P., Slade, T., Brownhill, S. & Andrews, G. (2003). Prevalence and correlates of DSM-IV major depression in an Australian national survey. *Journal of Affective Disorders*, 75, 155-162.

Willemse-van Son, A.H.P., Ribbers, G.M., Verhagen, A.P. & Stam, H.J. (2007). Prognostic factors of long-term functioning and productivity after traumatic brain injury: a systematic review of prospective cohort studies. *Clinical Rehabilitation*, 21, 1024-1037.

Williams, D.H., Levin, H.S. & Eisenberg, H.M. (1990). Mild head injury classification. *Neurosurgery*, 27(3), 422-428.

Wilson, B.A., Alderman, N., Burgess, P.W., Emslie, H. & Evans, J.J. (2003). Behavioural assessment of the dysexecutive syndrome (BADS). *Journal of Occupational Psychology, Employment and Disability*, 5(2), 33-37.

Winefield, A.H. & Tiggemann, M. (1990). Employment status and psychological well-being: a longitudinal study. *Journal of Applied Psychology*, 75(4), 455-459.

Wood, R.L.L. & Rutterford, N.A. (2006b).The effect of litigation on long-term cognitive and psychosocial outcome after severe brain injury. *Archives of Clinical Neuropsychology*, 21, 239-246.

World Health Organisation (WHO) (2005). *Promoting mental health: concepts, emerging evidence, practice.* A report of the WHO, Department of Mental Health and Substance Abuse in collaboration with the Victorian Health Promotion Foundation and the University of Melbourne by Herman, Saxena, and Moodie (eds). Retrieved 09 January 2010 from http://www.who.int/

World Health Organization. (1993). *The ICD-10 Classification of Mental and Behavioral Disorders: Clinical Descriptions and Diagnostic Guidelines*. Geneva: World Health Organization.

Youngjohn, J.R., Davis, D. & Wolf, I. (1997). Head injury and the MMPI-2: paradoxical severity effects and the influence of litigation. *Psychological Assessment*, 9(3), 177-184.

Zakzanis, K.K., Leach, L. & Kaplan, E. (1999). Mild traumatic brain injury. In *Neuropsychological differential diagnosis* (pp. 163-171). Exton, Pennsylvania: Swets & Zeitlinger.

Zumstein, M.A., Moser, M., Mottini, M., Ott, S.R., Sadowski-Cron, C., Radanov, B.P., Zimmermann, H. & Exadaktylos, A. (2011). Long-term outcome in patients with mild traumatic brain injury: a prospective observational study. *Journal of Trauma*, 71, 120-127.

APPENDIX A: Level of support for each pre-injury, peri-injury and post-injury variables examined

Level of support for each pre-injury variable examined

Study	Variables										
	Age	Sex	Education	IQ	Occupation	SES	Army rank	Income	Prior head injury	Marital status	Race/ Ethnicity
Friedland (2001)					+						
Ruffolo (1999)	n/s	n/s	n/s		+					n/s	
Doctor 2005)											
Dawson (2004)	_										
Reynolds (2003)											
Stulemeijer (2008)			+								
Vanderploeg (2003)	n/s		n/s	+							n/s
Hanlon (1999)	_	n/s							n/s		
Bazarian (2010)	n/s	n/s						+	n/s		n/s
Benedictus (2010)											
Stulemeijer (2006)											
Nolin (2006)	n/s	n/s									
Van der Naalt (1999)											
Paniak (1998)											
Stranjalis (2004)	n/s	n/s			n/s						
McCullagh (2001)											
Guerin (2006)	_	n/s	n/s								
Drake (2000)	+		n/s	n/s			+				
Rimel (1981)	+	n/s	+		+	+		+			
Paniak (2000)	_	n/s				n/s			n/s		
Level of Support	Mixed	Strong (n/s)	Weak (+)	More studies needed	Strong (+)	More studies needed	More studies needed	More studies needed	Strong (n/s)	More studies needed	More studies needed

+ Significant positive relationship between variable and return to work.
- Significant negative relationship between variable and return to work.
n/s No significant relationship between variable and return to work

Level of support for each pre-injury variable examined

Study	Variables								
	Living Arrangements	Insurance	Emotional/ Psychiatric problems	Pain medication use	Physical/ medical problems	Adverse life events	Neurological diagnosis	Area of residence	ETOH use
Friedland (2001)									
Ruffolo (1999)	n/s								
Doctor 2005)									
Dawson (2004)									
Reynolds (2003)									
Stulemeijer (2008)									
Vanderploeg (2003)			_		n/s			n/s	
Hanlon (1999)			n/s						
Bazarian (2010)				n/s					
Benedictus (2010)									
Stulemeijer (2006)									
Nolin (2006)									
Van der Naalt (1999)									
Paniak (1998)									
Stranjalis (2004)									
McCullagh (2001)									
Guerin (2006)		_	n/s		n/s		n/s		
Drake (2000)									
Rimel (1981)		n/s				_			
Paniak (2000)			n/s			n/s			n/s
Level of Support	More studies needed	More studies needed	Strong (n/s)	More studies needed	More studies needed	More studies needed	More studies needed	More studies needed	More studies needed

+ Significant positive relationship between variable and return to work.
- Significant negative relationship between variable and return to work.
n/s No significant relationship between variable and return to work.

Level of support for each peri-injury variable examined

Study	Variable					
	GCS	LOC	Extracranial injuries/ISS	Injury mechanism	CT scan results (NAD)	PTA
Friedland (2001)						
Ruffolo (1999)	n/s	n/s	n/s			
Doctor 2005)					+	
Dawson (2004)			_			
Reynolds (2003)						
Stulemeijer (2008)			_	+	+	
Vanderploeg (2003)		n/s				
Hanlon (1999)		n/s		+	n/s	
Bazarian (2010)	n/s	n/s	_	+	+	
Benedictus (2010)						
Stulemeijer (2006)			_			
Nolin (2006)	n/s					n/s
Van der Naalt (1999)						_
Paniak (1998)	n/s	n/s				
Stranjalis (2004)		n/s		n/s		n/s
McCullagh (2001)	n/s				n/s	
Guerin (2006)	n/s		n/s		n/s	
Drake (2000)	n/s	n/s				n/s
Rimel (1981)	n/s	n/s	n/s			
Paniak (2000)			n/s			n/s
Level of Support	Strong (n/s)	Strong (n/s)	Mixed	Strong (+)	Mixed	Strong (n/s)

+ Significant positive relationship between variable and return to work.
- Significant negative relationship between variable and return to work.
n/s No significant relationship between variable and return to work.

Level of support for each peri-injury variable examined

Study	Variables						
	Medication in ED	Retrograde amnesia	Symptoms at ED	Processing speed	Reaction time	Serum S-100B	Direct impact to head (y)
Friedland (2001)							
Ruffolo (1999)				n/s	n/s		
Doctor 2005)							
Dawson (2004)							
Reynolds (2003)							
Stulemeijer (2008)			_				
Vanderploeg (2003)							
Hanlon (1999)							
Bazarian (2010)	+						
Benedictus (2010)							
Stulemeijer (2006)							
Nolin (2006)		n/s	n/s				
Van der Naalt (1999)							
Paniak (1998)				n/s	n/s		
Stranjalis (2004)			n/s			_	
McCullagh (2001)							
Guerin (2006)			_				n/s
Drake (2000)							
Rimel (1981)							
Paniak (2000)	n/s						
Level of Support	More studies needed	More studies needed	Mixed	More studies needed	More studies needed	More studies needed	More studies needed

+ Significant positive relationship between variable and return to work.
- Significant negative relationship between variable and return to work.
n/s No significant relationship between variable and return to work.

Level of support for each post-injury variable examined

Study	Variables									
	Verbal memory	Processing speed	Executive functioning	Reaction time	Litigation/ compensation (y)	Discharge disposition	Sickness Impact Profile	Social interaction	Subjective problems	Fatigue
Friedland (2001)										
Ruffolo (1999)		n/s		n/s		+	n/s	+		
Doctor 2005)										
Dawson (2004)	+									
Reynolds (2003)					–					
Stulemeijer (2008)										–
Vanderploeg (2003)										
Hanlon (1999)	+		+		n/s					
Bazarian (2010)										
Benedictus (2010)										
Stulemeijer (2006)										
Nolin (2006)	+	n/s	n/s						–	
Van der Naalt (1999)										
Paniak (1998)										
Stranjalis (2004)										
McCullagh (2001)										
Guerin (2006)										
Drake (2000)	+		+						+	
Rimel (1981)										
Paniak (2000)					–					
Level of Support	Strong (+)	More studies needed	Strong (+)	More studies needed	Mixed	More studies needed	More studies needed	More studies needed	More studies needed	More studies needed

+ Significant positive relationship between variable and return to work.
- Significant negative relationship between variable and return to work.
n/s No significant relationship between variable and return to work.

Level of support for each post-injury variable examined

Study	Variables									
	PCS	Pain	Self-efficacy	Digit Span	Visual Reproduction	Boston Naming test	COWAT	Judgement of Line Orientation	Finger tapping	Grooved Pegboard
Friedland (2001)										
Ruffolo (1999)										
Doctor 2005)										
Dawson (2004)										
Reynolds (2003)										
Stulemeijer (2008)	_	_								
Vanderploeg (2003)										
Hanlon (1999)				n/s	+	n/s	n/s	+	n/s	n/s
Bazarian (2010)										
Benedictus (2010)										
Stulemeijer (2006)										
Nolin (2006)										
Van der Naalt (1999)										
Paniak (1998)										
Stranjalis (2004)										
McCullagh (2001)										
Guerin (2006)		n/s								
Drake (2000)							+			
Rimel (1981)										
Paniak (2000)										
Level of Support	More studies needed	More studies needed	More studies needed	More studies needed	More studies needed	More studies needed	More studies needed	More studies needed	More studies needed	More studies needed

+ Significant positive relationship between variable and return to work.
- Significant negative relationship between variable and return to work.
n/s No significant relationship between variable and return to work.

Level of support for each post-injury variable examined

Study	Variable			
	Depression	DOS cognitive	DOS behavioural	Treatment
Friedland (2001)				
Ruffolo (1999)				
Doctor 2005)				
Dawson (2004)				
Reynolds (2003)				
Stulemeijer (2008)				
Vanderploeg (2003)				
Hanlon (1999)	_			
Bazarian (2010)		_	_	
Benedictus (2010)				
Stulemeijer (2006)				
Nolin (2006)				
Van der Naalt (1999)				
Paniak (1998)				_
Stranjalis (2004)				
McCullagh (2001)				
Guerin (2006)	n/s			
Drake (2000)				
Rimel (1981)				
Paniak (2000)				
Level of Support	More studies needed	More studies needed	More studies needed	More studies needed

+ Significant positive relationship between variable and return to work.
- Significant negative relationship between variable and return to work.
n/s No significant relationship between variable and return to work.

APPENDIX B: Study Interview Sheets

Baseline Assessment Interview Sheet

Date Tested: ____/____/____ **Tested by:** _______ **Subject No:** _________

Group: 1. MVA MTBI 2. Non-MVA MTBI 3. MVA Control 4. Non-MVA Control

Mechanism of Injury:

MVA:

1. Driver
2. Passenger
3. Motorcyclist
4. Pedestrian
5. Cyclist
6. Other

Non-MVA

7. Fall
8. Assault
9. Stabbing
10. Firearm
11. Sporting accident

Phone Number: **Home:** ___________________ **Mobile:** ____________________

Email Address: ____________________________________

If you change address or move in the next few months can you tell me some other numbers where I could leave a message for you so that we can arrange follow up at 3 months or 1 year?

Other telephone numbers for contact:

1 _____________________________ 2 ____________________________

PATIENT HISTORY

(Day 1 = Day of admission)

Date of birth: _____________________ **Days since accident**: ___________

Age: ___________ (years and months)

Sex: ____ 1. Male 2. Female **Handedness**: 1. Right 2. Left

Where were you born:_________________ **First Language**: _______________

1. Australia Second Language:_____________
2. Overseas 1. English only

If Overseas, Years in Australia: _______ 2. English and another language

(Code as 99 if not applicable)

EDUCATION

Years of Education Completed (excluding kindergarten): ____

(e.g. the School Certificate would be 10 years of education)

Years and Type of Further Education Completed: _____

Total No of Years *Fully* Completed (Primary School + High School + University):

1. 0-7 years
2. 8 years
3. 9-11 years
4. 12 years
5. 13-15 years
6. 16+ years

At school did you receive any of the following?

Speech therapy	Yes / No
Special education at school	Yes / No
Repeated one or more years of school	Yes / No
A diagnosis of Attention Deficit Disorder or Hyperactivity?	Yes / No
A diagnosis of Learning Disability	Yes / No
Did you have a history of behaviour problems or expulsions from school?	Yes / No

---

EMPLOYMENT HISTORY

Are you working at present? Yes / No (Student/Home Duties/Unemployed)

What is your occupation?

____

Occupation:

1. Professional/Technical

2. Manager/Clerical/Sales
3. Craftsman/Foreman (Skilled)
4. Operator/Service/Domestic/Farmer (Semiskilled)
5. Labourer/Process Worker (Unskilled)
6. Student
7. Home Duties
8. Unemployed

If currently working, how many months have you been in your current job? ______

On average, how many hours per week do you spend in paid employment? ______

MEDICAL HISTORY

Have you a history of?

Hypertension (High Blood Pressure) Yes / No
Diabetes Yes / No
Cerebrovascular Disease (Stroke) Yes / No
Cardiac Disease Yes / No
Other Medical/Neurological Illness Yes / No If yes, specify**:**
____
No Medical History Yes / No

Have you had a previous concussion, loss of consciousness or head injury? Yes / No

If Yes: **Did any of these result in a loss of consciousness?**
Yes / No
Or confusion?
Yes / No
Or a loss of memory for events before or after the injury? Yes / No

Previous LOC:
1. No history of loss of consciousness
2. One previous mild to moderate TBI / concussion
3. More than one previous mild to moderate TBI / concussion

Do you have a history of epilepsy/seizures? 0. No 1. Yes
Had you been using alcohol at the time of the accident/injury? 0. No 1. Yes

Had you been using drugs at the time of the accident/injury? 0. No 1. Yes

---

DRUG HISTORY

I'd now like to ask you about any history of drug use.
During the last 12 months have you had any …

Marijuana, cannabis or hash?
0. No 1. Yes

How often have you had ____________________
How much do you usually have _______________ cones/joints per day

Ecstasy, speed or cocaine?
0. No 1. Yes

How often have you had ____________________
How much do you usually have _______________ grams/tabs/hits per week

Heroin, morphine or methadone?
0. No 1. Yes

How often have you had ____________________
How much do you usually have _______________ grams/mills/hits/tabs per day

Other drugs such as sleeping tablets or sedatives (like valium or normison), drugs like LSD or painkillers, or drugs you sniff like petrol or glue? 0. No 1. Yes

How often have you had ____________________
How much do you usually have ____

PSYCHOLOGICAL HISTORY

Have you ever had emotional or psychological difficulties?
____

Have you ever seen a counsellor/psychologist/psychiatrist?
____

What was that for?
____

Psychological History:

Marital problems	Yes / No
Personality Disorder	Yes / No
Depression	Yes / No
Substance Abuse	Yes / No
Anxiety	Yes / No
Bereavement	Yes / No
Posttraumatic Stress Disorder	Yes / No
Other (specify:_____)	Yes / No
Schizophrenia /Psychosis	Yes / No
No Psychological History	Yes / No

DETAILS OF ACCIDENT

On what date were you admitted to hospital? (Name of hospital if not Westmead)

____

How did you get here/there? ____

When did you first become aware that an accident had taken place?

____
____
____
____

Did you lose consciousness or feel dazed or confused? __________

IF YES: For how long? _______________________________________(Generally use the NSW Ambulance report as the most informed information for LOC unless witnessed by another person)

1. No loss of consciousness
2. Alteration in mental state (dazed, disoriented or confused)
3. Loss of consciousness up to 5 minutes
4. Loss of consciousness 6 minutes to 30 minutes
5. Unknown

What have you been told about the accident/injury and how it happened? (By whom)

____
____
____
____

<u>Retrograde Amnesia</u>

Can you describe in detail the last event or what was happening BEFORE the accident? (GOAT, 1979) (Prompt by asking "what happened next")(Always ask "can you remember the impact" and/or "all details up to the impact", for **both MTBI and controls)**

____
____
____
____
____
____

What time do you think it was? ____

Retrograde Amnesia

1. None
2. Up to 5 minutes
3. 6 minutes to 30 minutes
4. 31 to 60 minutes
5. 61 minutes to 12 hours
6. Unknown

<u>Posttraumatic Amnesia</u>

Can you describe in detail the first event you can remember AFTER the injury? Prompt by asking "what happened next" to establish that the individual has detailed ongoing , memories, and therefore out of PTA, rather than an island of memory.

____
____
____
____
____
____
____
____
____
____
____
____
____
____
____

What time do you think it was? ____

Posttraumatic Amnesia-

1. None
2. Up to 5 minutes
3. 6 minutes to 30 minutes
4. 31 minutes to 60 minutes
5. 61 minutes to 12 hours
6. 12 hours to 24 hours
7. Unknown

Do you think that any drugs or alcohol you took before the event decreased your memory of the event? Yes / No

<u>Numerical Rating Scale of Pain Intensity</u>

On a scale of 0 to 10, with 0 being NO PAIN and 10 being PAIN AS BAD AS IT COULD BE, could you rate your pain at the time of the accident/injury?

0 1 2 3 4

No Pain Pain as bad as it could be

(Code as 99 if amnesic to events and unable to recall)

On the same scale of 0 to 10, with 0 being NO PAIN and 10 being PAIN AS BAD AS IT COULD BE, could you rate your pain, in general, now?

0 1 2 3

No Pain

ADMINISTER POST CONCUSSIVE CHECKLIST

CALCAP RESULTS:	**Mean RT**	**Z-Score**	**True +'s**	**False +'s**
Simple RT	________	________		
Choice RT	________	________	____ / ____	____ / ____
Sequential RT – Time 1	________	________	____ / ____	____ / ____
Sequential RT – Time 2	________	________	____ / ____	____ / ____

3 Month Assessment Interview Sheet

Patient Label Here **Date of Assessment: ____ / ____**
/ ____ **Subject No: __________**
Tested By: ________________

Date Admitted to Hospital: ___________________ (Day 1 = Day of Admission)
Date Discharged from Hospital: _______________
Number of Days Spent in Hospital: _____________ Date of Time 1 Assessment___________

Days From Initial Assessment to When Seen for Follow-Up ____________________________
(include day of initial assessment = Day 1, & day of current assessment)

Injury Severity Score: _______________ (From Trauma Database)

Thankyou for coming in to participate in the follow-up for the study.

Today, I'll be asking you questions about your return to work and recovery. I'll then ask you to do a number of different kinds of tasks. I'll be asking you about things you have already learned, or I'll give you arithmetic or memory problems. Other tests will be similar to puzzles. Some things you may find fun and some silly; some of the tests will be very easy and others will be designed so that it will be difficult for you to get past a certain level. The testing is not like a school examination where you pass or fail. Most people don't answer every question correctly of finish every item. Within some tests are built in indicators that estimate the effort you have made so please give your best effort on all the tests. Do you have any questions?

<u>Return to Work/Study/Home Duties</u>

I'm going to ask you some questions about your work (e.g. paid and/or voluntary).

What would have been your average number of hours per week at work prior to your injuries? _________hours (**Code as 99 if not applicable e.g. unemployed or on a pension)**

On average how many hours per week did you spend in work in the past month?__________hours **(Code as 99 if not applicable)(0 if person on annual/sick leave)**
If returned to work:

Have you
1. Returned to work full time injury
2. Returned to part time work

Are your duties at work at
1. The same level as before the
2. A reduced level, or

3. Not returned to work at all
   duties
9. **Not applicable**

3. Are you performing different
9. **Not applicable**

If fully returned to pre-injury number of hours of work ask: (Code 999 if N/A)
How long were you totally off work because of your injuries?_________days
How long were you partially off work because of your injuries?_______ days

If partially returned to pre-injury number of hours of work, ask: (Code 999 if N/A)

How long were you totally off work because of your injuries?__________days

If a <u>student</u> (or also working and a student): (Code 999 if N/A e.g. not studying)

What would have been your average hours per week spent studying prior to your injuries?
________ hours **(includes attending class and studying)**

What was your average hours per week spent studying in the past month? ________
hours

Have you
1. Returned to study at the same hours as before the accident
2. Returned to study at reduced hours
3. Not returned to study at all
9. **Not applicable**

If also performing <u>home duties</u>: (Code 999 if N/A)

What would have been you average hours per week performing home duties prior to your injuries? ________ hours (**includes housework, parenting, cooking, gardening, repairs)**

What was your average hours per week spent doing home duties in the past month?
________ hours

Have you
1. Returned to home duties at the same hours as before the accident
2. Returned to home duties at reduced hours
3. Not performing home duties at all
9. **Not applicable**

Have you returned to driving a car? If no - Why is that?____________________

1. Returned to
   license
   driving

2. Lost license before
   accident

3. Not returned to driving
   due to accident/injury

4. Lost
   since
   accident

9 . Not applicable

Psychological History

Have you had any emotional problems or difficulties since the accident?

If Yes: What has happened?

____

Have you seen a counsellor, psychologist or psychiatrist for treatment since the accident/injury? If Yes, what was that for?________________________________

(score reasons for emotional problems and/or for treatment)

Marital problems **N/Y** Personality Disorder **N/Y**

Depression **N/Y** Substance Abuse **N/Y**

Anxiety **N/Y** Bereavement **N/Y**

Posttraumatic Stress Disorder **N/Y** Other__________ **N/Y**

Schizophrenia / Psychosis **N/Y** Psychol. problems (history) **N/Y**

Numerical Rating Scale of Pain Intensity

On a scale of **0 to 10** with **0 being NO PAIN** and **10 being PAIN AS BAD AS IT COULD BE** could you rate , in general, your pain now?

0 1 2 3 4 5 6 7 8 9 10

No Pain

Pain as bad

as it could be

Recovery

It has been ________ months / ______ year since the accident/injury.

On a scale of **0 to 10**, with **0 representing no recovery**, and **10 complete recovery** how would you, in general, rate your recovery?

0 1 2 3 4 5 6
7 8 9 10

No recovery

Complete

recovery

Medication

Are you currently taking any medications for pain, at least once a week on a regular basis?

Date and Time	Medication	Route	Dosage

None 0. No 1. Yes
NonNarcotic Analgesia 0. No 1. Yes(e.g. Simple Analgesia-Panadol, Antinflammatory-Neurofin)
Codeine 0. No 1. Yes
Tramadol 0. No 1. Yes
Methadone 0. No 1. Yes
Other Narcotic 0. No 1. Yes

Alcohol History:

I'd like to ask you to fill in some questions about your drinking history since the accident. Ask participant to fill in AUDIT

AUDIT SCORE: ________ **AUDIT hazardous/harmful drinking:** 0. No 1. Yes

Drug Use:

During the time since the accident have you had any?

Marijuana, cannabis or hash? **0. No** **1. Yes**

How often have you had ____________________
How much do you usually have _______________ cones/joints per day

Ecstasy, speed or cocaine?
0. No 1. Yes

How often have you had ____________________
How much do you usually have _______________ grams/tabs/hits per week

Heroin, morphine or methadone?
0. No 1. Yes

How often have you had ____________________
How much do you usually have _______________ grams/mills/hits/tabs per day

Other drugs such as sleeping tablets or sedatives (like valium or normison), drugs like LSD or painkillers, or drugs you sniff like petrol or glue? 0. No 1. Yes

How often do you have ____________________
How much do you usually have ____

Seeking financial compensation:

Are you involved in litigation as a consequence of the event that caused your injuries?

0. No 1. Yes 2. Don't know

If Yes:

Are you seeking compensation?

0. No 1. Yes 2. Don't know **9. N/A**

Have claims been made against you?

0. No 1. Yes 2. Don't know **9. N/A**

Has your litigation been resolved?

0. No 1. Yes **9. N/A**

Administer Post-Concussive Checklist

WORD MEMORY TEST:

Number Correct - IR: ________ / 40

Number Correct - DR: ________ / 40

Overall Consistent - IR Versus DR: ________ / 40

CALCAP RESULTS:

	Mean RT	True +'s	False +'s
Simple RT	________		
Choice RT	________	_____ / 15	_____ / 85
Sequential RT – Time 1	________	_____ / 20	_____ / 80
Sequential RT – Time 2	________	_____ / 20	_____ / 80

ADAPTIVE CATEGORY TEST:

Predicted Final Score - Total: ________

Scaled Score: ________

T-Score: ________

FROM MEDICAL RECORD CHECK TIME 1 MEDS & NO. OF G.A.'S

Retrograde Amnesia

Can you describe in detail the last event or what was happening BEFORE the accident? (GOAT, 1979) (Prompt by asking "what happened next")(Always ask "can you remember the impact" and/or "all details up to the impact", for **both MTBI and controls)**

____

____

____

____

____

____

<u>Posttraumatic Amnesia</u>

Can you describe in detail the first event you can remember AFTER the injury?
Prompt by asking "what happened next".

APPENDIX C: Preliminary Data Analysis

Tests of Assumptions for WSRT A and B – Homogeneity of Variances

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
T1CLTRAB List A and B CLTR-Westmead SRT	Equal variances assumed	.619	.433	.746	110	.457	2.86	3.829	-4.733	10.444
	Equal variances not assumed			.730	85.435	.467	2.86	3.911	-4.919	10.631

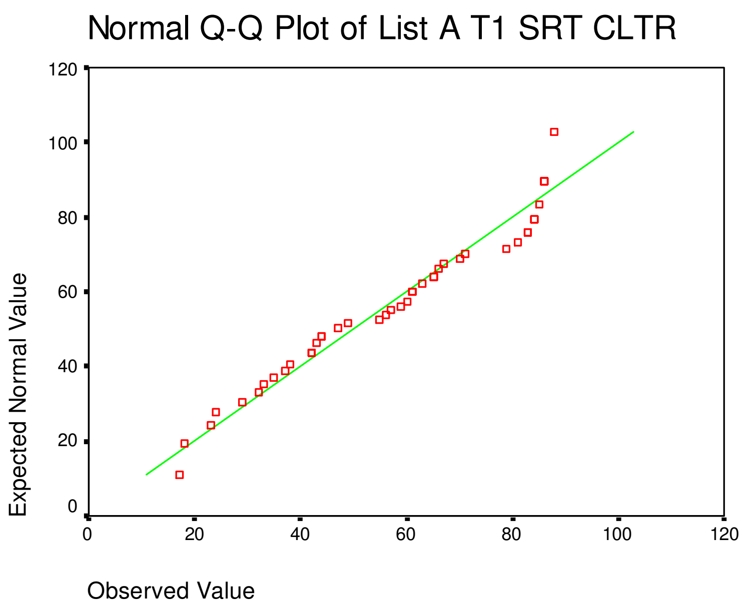
Tests of Assumptions for WSRT A and B – Normality Test

One-Sample Kolmogorov-Smirnov Test

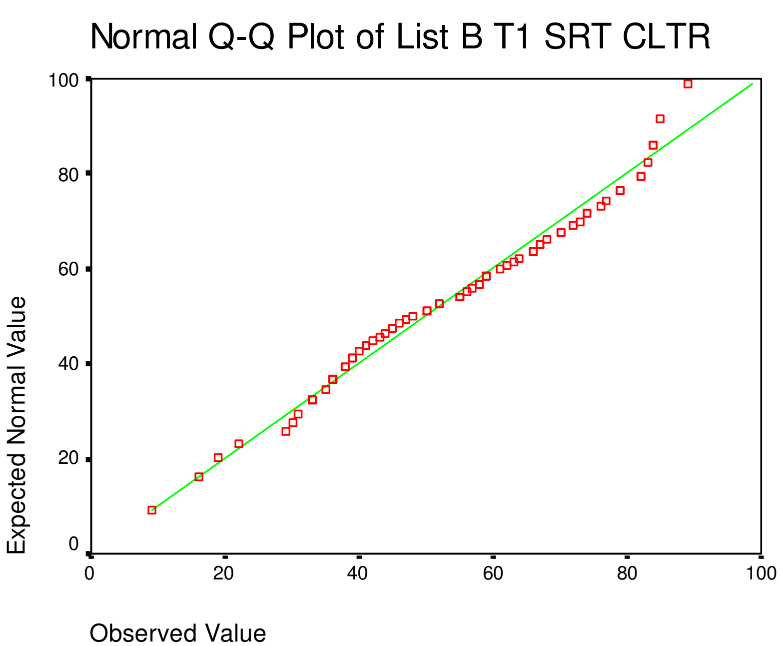
		T1CLTR_A List A T1 SRT CLTR	T1CLTR_B List B T1 SRT CLTR
N		44	68
Normal Parameters(a,b)	Mean	56.84	53.99
	Std. Deviation	20.955	19.009
Most Extreme Differences	Absolute	.105	.064
	Positive	.094	.064
	Negative	-.105	-.060
Kolmogorov-Smirnov Z		.695	.529
Asymp. Sig. (2-tailed)		.719	.942

a Test distribution is Normal.
b Calculated from data.

Tests of Assumptions for WSRT List A – Normality Q-Q Plot



Tests of Assumptions for WSRT List B – Normality Q-Q Plot



APPENDIX D: Unpaired t-test for WSRT List A and List B

Group Statistics

	T1WSRT T1 WSRT List A or B	N	Mean	Std. Deviation	Std. Error Mean
T1CLTRAB List A and B CLTR-Westmead SRT	1 List A	44	56.84	20.955	3.159
	2 List B	68	53.99	19.009	2.305

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
T1CLTRAB List A and B CLTR-Westmead SRT	Equal variances assumed	.619	.433	.746	110	.457	2.86	3.829	-4.733	10.444
	Equal variances not assumed			.730	85.435	.467	2.86	3.911	-4.919	10.631

APPENDIX E: Univariate Description of Sample and Normality Test Output

Frequencies of Demographic and Injury Variables

Statistics

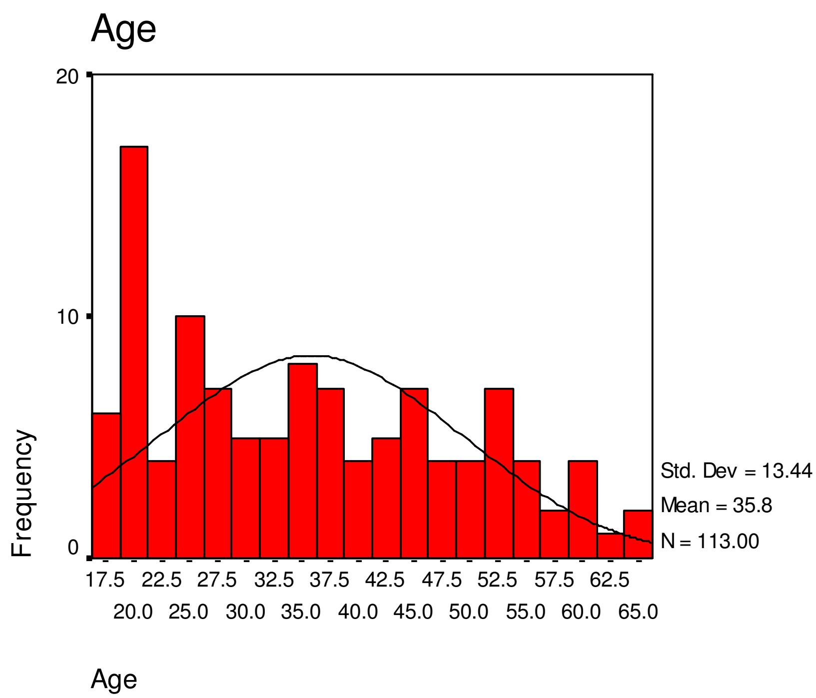
		Age	Sex	Years of Education	WTAR	Income (6 groups)	Previous mtbi (0 = no; 1 = yes)	Injury Mechanism	Pain Intensity	Length of Hospital stay	Litigation or compensation
N	Valid	113	113	113	113	111	113	112	113	113	106
	Missing	0	0	0	0	2	0	1	0	0	7
Mean		35.8031	.34	11.57	100.90	3.48	.30	2.77	3.61	7.32	1.59
Std. Error of Mean		1.26437	.045	.244	.886	.147	.043	.155	.238	.649	.048
Median		34.0800	.00	11.00	102.00	4.00	.00	3.00	3.00	6.00	2.00
Std. Deviation		13.44047	.475	2.594	9.417	1.548	.461	1.638	2.533	6.898	.493
Variance		180.64635	.225	6.730	88.678	2.397	.212	2.684	6.418	47.576	.243
Skewness		.360	.702	1.696	-.313	-.077	.880	.444	.693	3.385	-.390
Std. Error of Skewness		.227	.227	.227	.227	.229	.227	.228	.227	.227	.235
Kurtosis		-1.037	-1.534	4.570	.652	-1.050	-1.248	-1.107	-.024	14.761	-1.884
Std. Error of Kurtosis		.451	.451	.451	.451	.455	.451	.453	.451	.451	.465
Range		46.11	1	17	55	5	1	5	10	45	1
Minimum		18.00	0	6	70	1	0	1	0	2	1
Maximum		64.11	1	23	125	6	1	6	10	47	2
Percentiles	25	24.0450	.00	10.00	95.00	2.00	.00	1.00	2.00	4.00	1.00
	50	34.0800	.00	11.00	102.00	4.00	.00	3.00	3.00	6.00	2.00
	75	46.5450	1.00	12.00	106.50	5.00	1.00	4.00	5.00	8.00	2.00

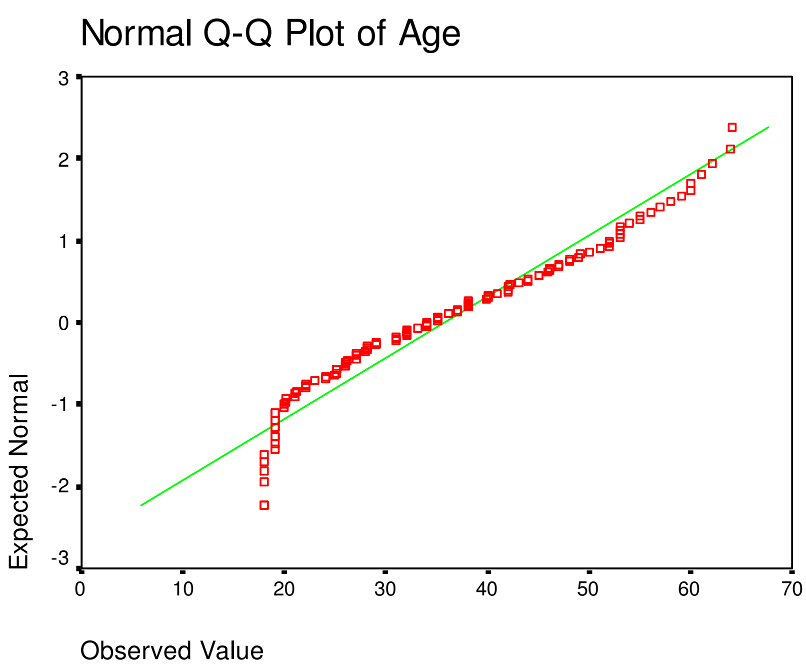
Tests of Normality

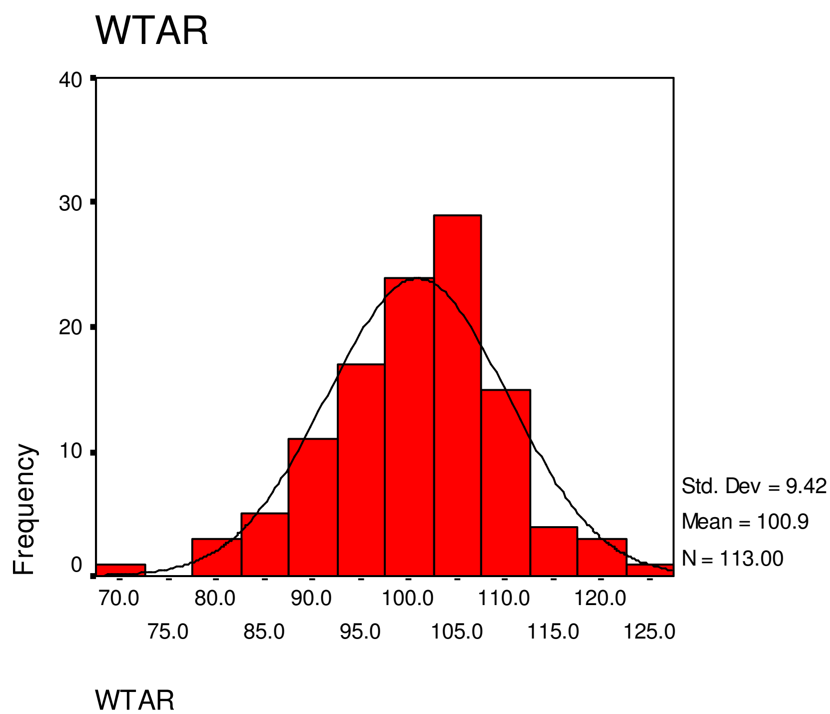
	Kolmogorov-Smirnov(a)			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
AGE Age	.105	69	.057	.951	69	.009
WTAR WTAR	.106	69	.053	.976	69	.201
MEDSDAY1 Medication Day1 (day of ax)	.227	69	.000	.760	69	.000
T1_PAIN T1 Pain Intensity	.147	69	.001	.942	69	.003
DAYS_HSP Length of Hospital stay	.243	69	.000	.667	69	.000
YRS_EDU Years of Education	.285	69	.000	.823	69	.000

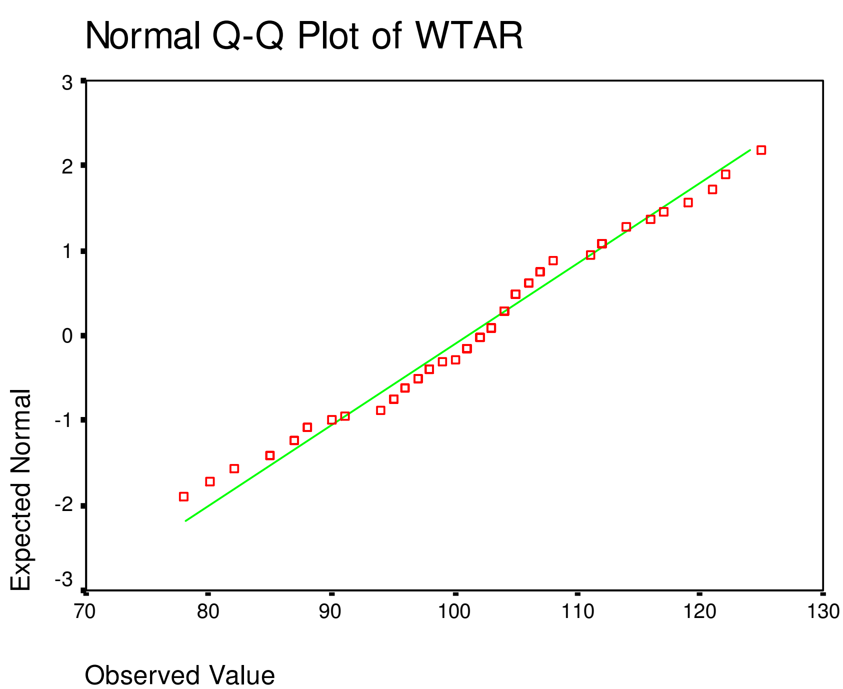
a Lilliefors Significance Correction

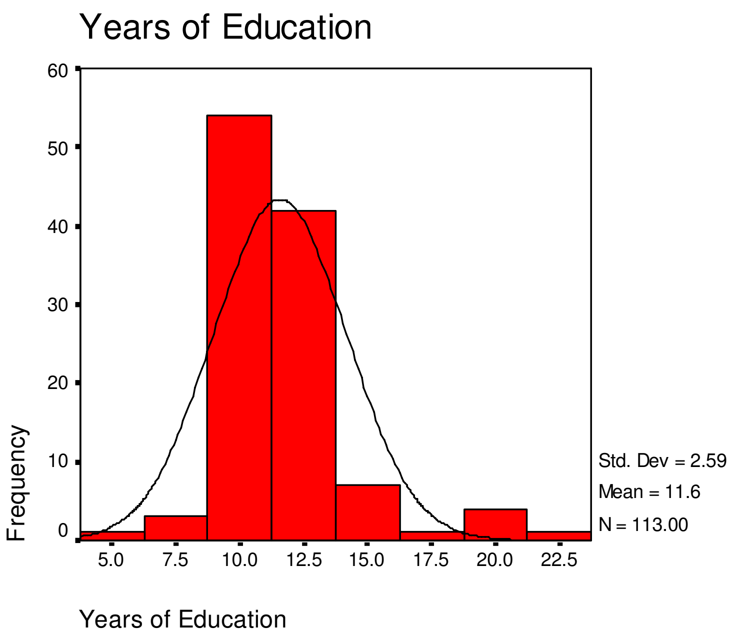
Graphical Display of Demographic and Injury Variables

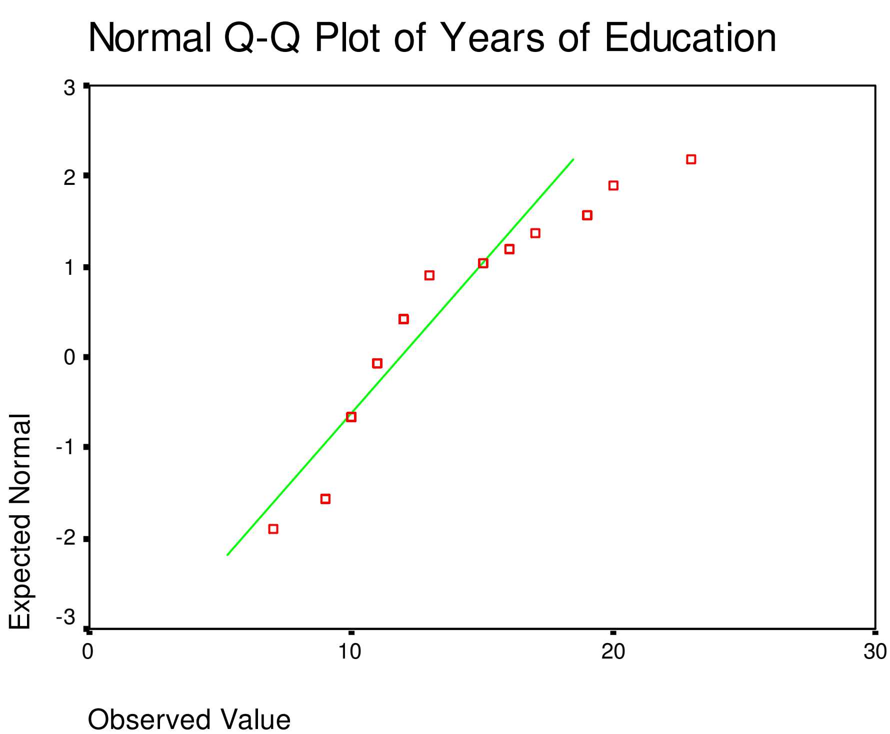


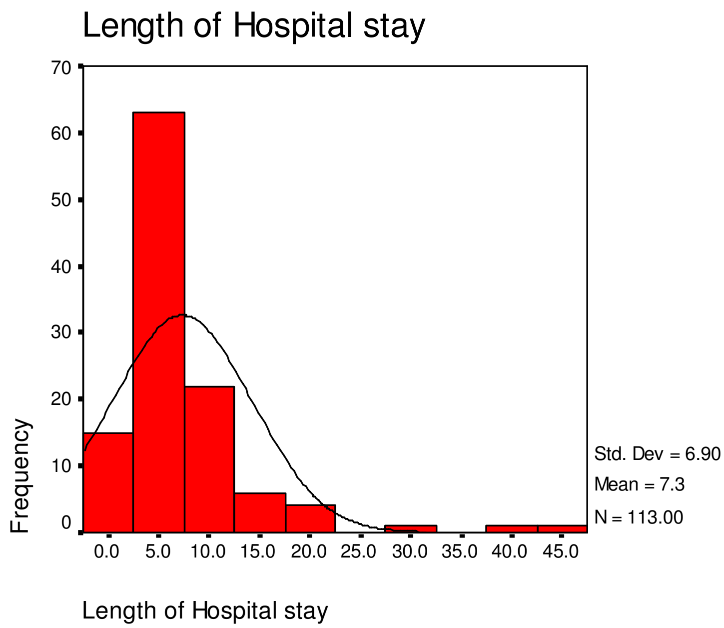


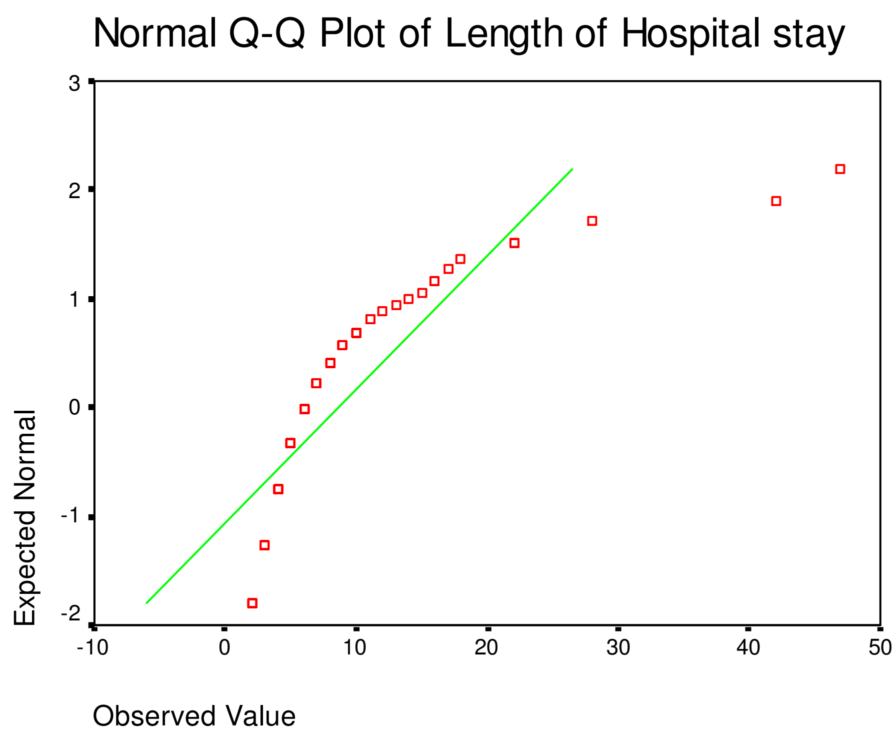

WTAR
40
30
20
10
0
Frequency
70.0
80.0
90.0
100.0
110.0
120.0
75.0
85.0
95.0
105.0
115.0
125.0
WTAR
Std. Dev = 9.42
Mean = 100.9
N = 113.00

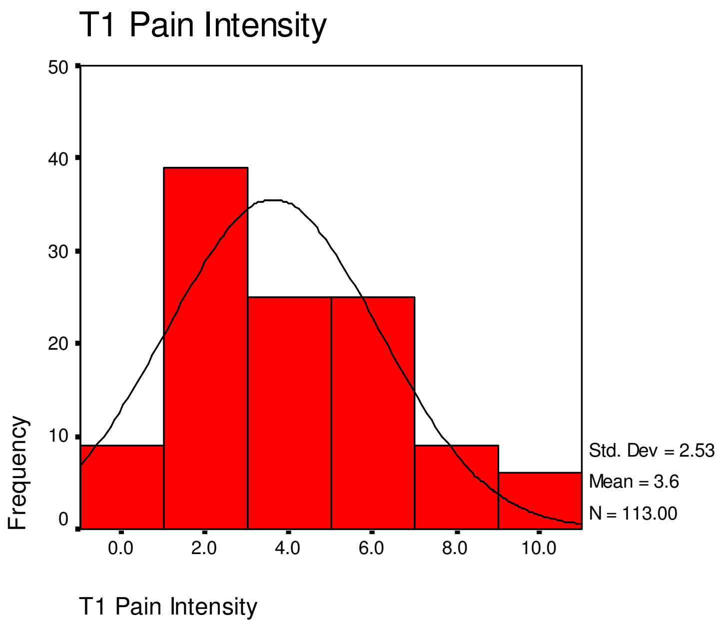

Normal Q-Q Plot of WTAR
3
2
1
0
-1
-2
-3
Expected Normal
70
80
90
100
110
120
130
Observed Value

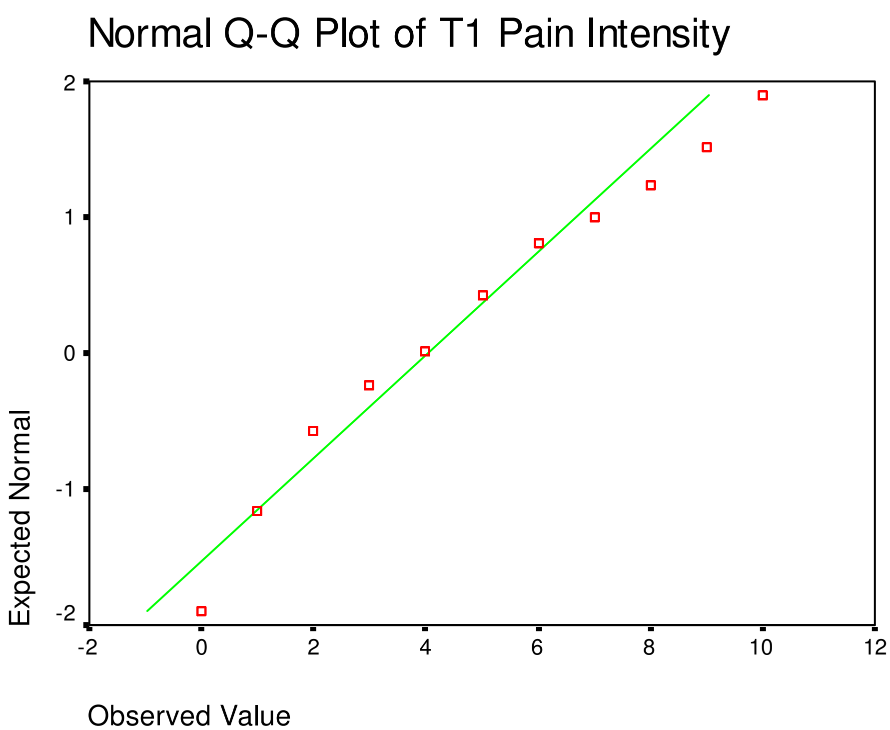

Years of Education
60
50
40
30
20
10
0
Frequency
5.0
7.5
10.0
12.5
15.0
17.5
20.0
22.5
Std. Dev = 2.59
Mean = 11.6
N = 113.00
Years of Education

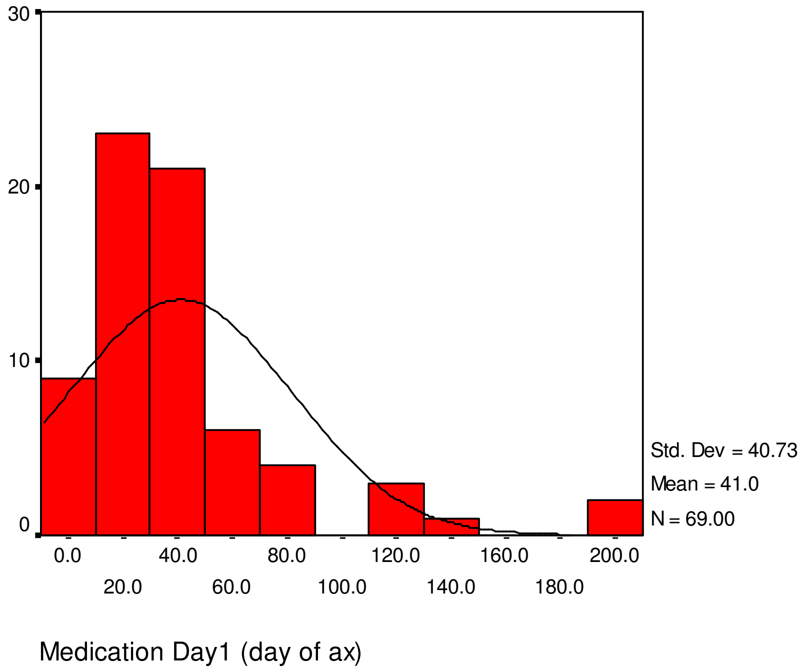

Normal Q-Q Plot of Years of Education
3
2
1
0
-1
-2
-3
Expected Normal
0
10
20
30
Observed Value

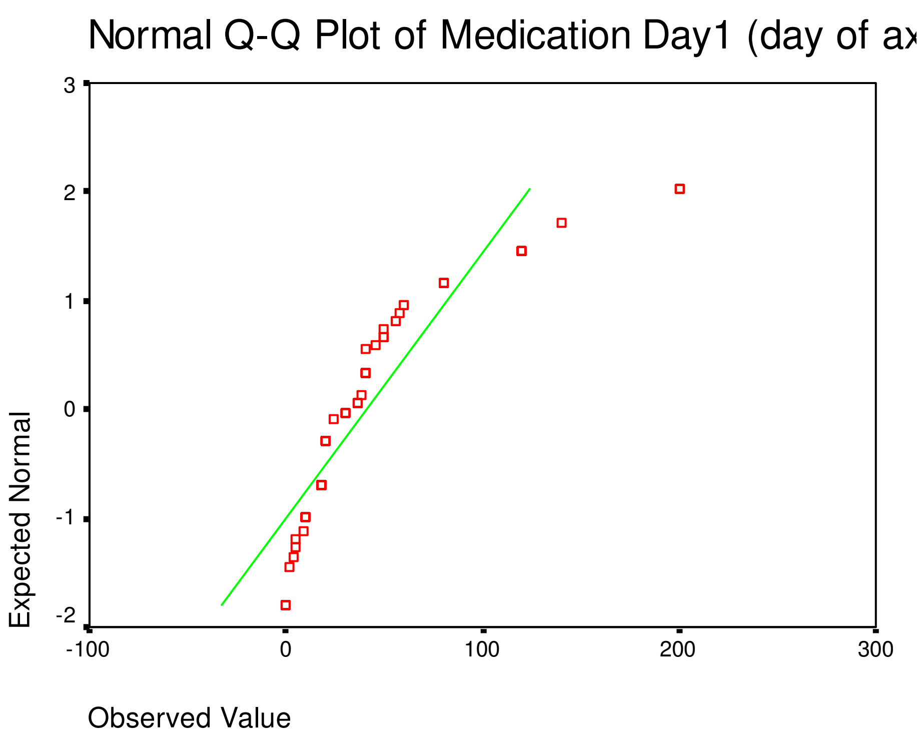

Length of Hospital stay
70
60
50
40
30
20
10
0
Frequency
0.0
5.0
10.0
15.0
20.0
25.0
30.0
35.0
40.0
45.0
Length of Hospital stay
Std. Dev = 6.90
Mean = 7.3
N = 113.00


Normal Q-Q Plot of Length of Hospital stay
3
2
1
0
-1
-2
Expected Normal
-10
0
10
20
30
40
50
Observed Value


T1 Pain Intensity
50
40
30
20
10
0
Frequency
0.0
2.0
4.0
6.0
8.0
10.0
Std. Dev = 2.53
Mean = 3.6
N = 113.00
T1 Pain Intensity


Normal Q-Q Plot of T1 Pain Intensity
2
1
0
-1
-2
Expected Normal
-2
0
2
4
6
8
10
12
Observed Value


30
20
10
0
0.0
20.0
40.0
60.0
80.0
100.0
120.0
140.0
160.0
180.0
200.0
Std. Dev = 40.73
Mean = 41.0
N = 69.00
Medication Day1 (day of ax)


Normal Q-Q Plot of Medication Day1 (day of ax
Expected Normal
3
2
1
0
-1
-2
-100
0
100
200
300
Observed Value

APPENDIX F: Results of the Chi-squared analysis of the relationship between PTA duration and return to productivity for mTBI group.

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)
Pearson Chi-Square	5.372(a)	3	.147	.147
Likelihood Ratio	5.480	3	.140	.154
Fisher's Exact Test	5.047			.162
Linear-by-Linear Association	2.550	1	.110	.118
N of Valid Cases	56			

a. 3 cells (37.5%) have expected count less than 5. The minimum expected count is 3.38.

b. The standardized statistic is 1.597.