Mild Traumatic Brain Injury Burden in New Zealand:

A Population-based Incidence and Short Term Outcomes Study

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A thesis submitted in partial fulfilment of the requirements for the degree of Doctor of Clinical Psychology

The University of Auckland, September 2014

ABSTRACT

Traumatic brain injury (TBI) is a significant public health concern nationally and internationally. Mild TBI accounts for up to 90% of all TBIs. The majority of those who experience a mild TBI make a full recovery. However, despite the term "mild", an estimated 15% to 50% experience persistent symptoms which affect their personal, family and social lives (Bazarian & Atabaki, 2001). This study is a prospective population based study of mild TBI, which aimed to establish the true incidence of mild TBI; describe the short term outcome in patients with mild TBI; identify factors associated with persisting problems; and establish the usefulness of further categorising mild TBI for the purposes of predicting outcomes. Participants included all adult residents of Hamilton and Waikato districts in the central North Island of New Zealand (NZ), who sustained a new mild TBI between 1st March 2010 and 28th February 2011. Participants were assessed at baseline, one and six month follow-ups in the areas of neuropsychological functioning, health related quality of life functioning, social and community integration. The overall incidence for non-Māori was 301 per 100 000, with a substantially higher rate of 1,026 cases per 100 000 population for NZ's indigenous (Māori) people. These are considerably higher rates than those previously reported, highlighting the severity of this seemingly "mild" problem. In addition to this ethnic difference, other at risk groups includes males, those in the younger and the older age groups. In terms of outcomes, deficits in psychological, social, health related quality of life and cognitive functioning were evident within two weeks of injury; as expected, these improved overtime, except attention. Given the high incidence rates reported, and persistent deficits by six months post-injury, mild TBI no doubt warrants attention. These findings have implications for the management of mild TBI.

DEDICATION

This thesis is dedicated to my parents and my husband with gratitude for their unconditional love, support, and encouragement.

This thesis is also dedicated to my wonderful daughter who never ceases to amuse me.

ACKNOWLEDGEMENTS

I would like to acknowledge all the people who have contributed to this thesis.

This thesis would not have been possible without the participants and their families who generously offered their time. I am thankful for the help from the BIONIC team, without you this study would not have been achieved.

I am extremely grateful for my supervisor Associate Professor Suzanne Barker-Collo for your efficient feedback with my numerous drafts of this thesis. Your support, guidance, enthusiasm, and compassion for this study have been my guiding light throughout this journey.

I would like to offer my sincere appreciation to the staff in the Clinical Psychology programme. In particular I would like to acknowledge Fiona Howard for your immense support during my internship. Thank you also to Sheryl Robertson, whose hard work behind the scene is often not seen and acknowledged enough.

I am thankful to my classmates in the clinical programme you have been supportive and caring from the beginning.

I am grateful for my friends; you have been unbelievably considerate, patient and encouraging over the years.

I would like to express my gratitude to my siblings, Audrey, Kayley, and Darren; for your continual love and support. You have been incredibly understanding and accommodating of my absence during times when I have been so self absorbed with studying.

Words cannot express how grateful I am to my parents for all the sacrifices you have made for me, and for nurturing and encouraging me to pursue my goals.

Thank you also to my in-laws for taking care of my nutritional needs and unfailing care of Josie.

I am indebted to my husband Jordan, without whose love, support and sacrifices; I would not have embarked on this journey, and probably would not have completed it. You have an amazing ability to tune in to my needs. You have encouraged me when I wanted to give up, guided me when I felt lost, and brought me back to reality when I got so caught up with studying.

Special thanks to Audrey and June for the last minute proof reading and editing of this thesis.

I want to express my gratitude once again to all those mentioned above, completing this journey was only possible because of every one of you.

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CHAPTER I: INTRODUCTION TO TBI AND ITS EPIDEMIOLOGY

Introduction

Traumatic Brain Injury (TBI) is a major health concern and a leading cause of disability and death in young adults (Barker-Collo & Feigin, 2009). There are three subtypes of TBIs, mild, moderate and severe (Ogden, 2005), where mild TBI accounts for up to 90% of all TBIs (Cassidy et al., 2004). Despite the term mild, these injuries can have severe implications for the individual, their families, friends and the wider community. While the majority of those who experience a mild TBI will make a full recovery in the first three months, an estimated 15% to 50% experience persistent symptoms which affect their personal, family and social lives (Bazarian & Atabaki, 2001).

This study presents part of a larger Health Research Council (HRC) funded population based study of TBI in New Zealand (NZ). Participants included all adult residents of Hamilton and Waikato districts in the central North Island of NZ, who suffered a new mild TBI between 1st March 2010 and 28th February 2011. Participants were assessed within two weeks of injury, and at one and six month follow-ups. This study aimed to determine the annual incidence of mild TBI; describe the outcome in patients with mild TBI at one and six month post-injury and to identify demographic and injury related factors associated with persisting problems. In order to understand the impact of mild TBI, this chapter will first review definitions and subtypes of TBI, and look at the severity of this problem through examining the epidemiology and neuropathology of TBI. The initial sections begin with an examination of TBI more generally to provide a context for a more detailed examination of mild TBI as this is the focus of this study. Subsequent sections where there is data specific to mild TBI will focus only on mild TBI.

Traumatic Brain Injury

TBI definitions and types

TBI is broadly defined by the New Zealand Guidelines Group (NZGG) (2006) as "an injury to the brain resulting from externally inflicted trauma" (p. 21), this is in accordance with internationally accepted definitions of TBI such as that of the World Health Organisation (WHO). Whilst the terms TBI and head injury have been used interchangeably by some researchers, recent literature distinguishes between the two, where head injuries refer to visible injuries to the external surfaces of the head, such as the face, scalp, and calvarium, including lacerations, contusions, abrasions, and fractures (Bruns & Hauser, 2003a); while TBI is an injury to the brain itself rather than injuries to the head (NZGG, 2006).

TBI has been categorised in a number of ways. In regards to injury type, the most common categorisations used are open or penetrating, closed, and crushing brain injury (Gronwall, Wrightson, & Waddell, 1990; Ogden, 2005). Open brain injury accounts for about 10% of all TBIs (Grafman & Salazar, 1987; cited in Gronwall, et al., 1990). In an open brain injury, the skull is opened, broken or pierced, where the brain is exposed and damaged (Ogden, 2005). This is often the result of penetration by a sharp object such as a bullet (NZGG, 2006). Closed brain injury is by far the most common type (Ogden, 2005); and is where the skull is not broken open and brain tissue not penetrated; rather, damage to the brain is caused by rapid and forceful movement of the brain within the skull. This type of injury is typically caused by rapid acceleration or deceleration from a blunt object or from blunt impact of the head with a stationary object (Ponsford, Sloan, & Snow, 1996). The head is rocked back and forth or rotated, and the brain follows the movement of the skull, causing nerve fibres to be twisted, stretched and even torn in the process. Crushing head injury is the least common, with the main damage rarely

to the brain itself, but to the base of the skull and the nerves that run through it as this form of injury involves the head being caught between two objects (e.g., between the ground and the wheel of the car) (Gronwall, et al., 1990; Ogden, 2005).

Defining Mild, Moderate and Severe TBI

In addition to differing mechanisms of injury, TBI is often categorised in terms of severity based on acute injury characteristics. Researchers in the field classify TBI into three severity categories: mild, moderate, and severe. The majority of TBI cases fall in the mild category, and this is the focus of the current study. The aims of categorising TBI severity are to establish a case definition to guide clinicians in recognising the signs and symptoms of the injury, formulate an accurate diagnosis, and ultimately guide treatments (McCrea, 2008; Torner & Schootman, 1996). A consensus case definition also assists researchers in allowing comparison of epidemiological estimations and outcome research (McCrea, 2008). To date, a number of different classification criteria have been used in research studies; with most of these using criteria including the Glasgow Coma Scale (GCS), post-traumatic amnesia (PTA) and loss of consciousness (LOC).

The GCS is the most recognised and commonly used measure of TBI severity, especially during the acute stages (NZ Guidelines Group, 2006; McCrea, 2008; 2005). The GCS was first proposed and evaluated by Teasdale and Jennett (1974), and provides a classification based on depth of coma, allowing a measure of a patient's level of consciousness over time. The GCS is a 15-point scale that assesses motor responses (rated from 1=no motor response to 6=able to obey commands), verbal performance (rated from 1=no verbal response to 5=orientated), and eye movement (rated from 0=no eye opening to 4=spontaneous eye opening) (Ogden, 2005). The

most basic approach to grading TBI severity is based solely on GCS scores (McCrea, 2008). Generally, a score of 8 or lower is accepted as a severe TBI, a score of 9-12 is considered a moderate TBI, while a score of 13-15 is considered a mild TBI. These ratings provide guidance for intervention during the acute stage and predict early outcomes such as mortality and morbidity, as well as functional status and return to work during later stages, particularly for moderate and severe TBIs (Sherer, Struchen, Yablon, Wang, & Nick, 2008). Although the GCS is a popular assessment tool amongst both researchers and clinicians, there are some limitations to its utility, particularly for mild TBI. A large number of mild TBI patients score 15, the maximum score on the GCS. This significant ceiling effect suggests the GCS is not sensitive enough to pick up and to distinguish milder forms of TBI (McCrea, 2008). There is also disagreement about which GCS score should be recorded. Some believe it is important to obtain a GCS score as soon as possible after injury (e.g., at the scene of the accident) to capture the true severity of TBI, particularly for mild TBI patients who recover rapidly (Manzi & Weaver, 1987); while others argue that the patient should be assessed at least six hours after injury to avoid confounding factors such as drug and alcohol in the patient's system that can lead to a confused or comatose state (Ogden, 2005). However, this is not always possible as sometimes medical intervention is necessary during the early stages. Furthermore, if the patient is assessed after medical interventions, the accuracy and usefulness of the GCS ratings is affected as patient may be under the influence of medical procedures and drugs (Sherer, et al., 2008). Indeed, ratings on the GCS may be directly impacted by medical interventions such as administration of significant pain relief related to severe orthopaedic injury that accompany the TBI, tracheotomy, or the need for medically induced coma (Sherer, et al., 2008). In particular, later assessment is less relevant for mild TBI as their recovery is rapid (Sherer, et al., 2008). Thus, the GCS has limited utility

and sensitivity in detecting mild TBI. In relying solely on this scale one runs the risk of missing key diagnostic signs and symptoms not referenced by the scale, and ultimately under diagnosing mild TBI (McCrea, 2008). In practice, multiple GCS scores are often recorded (i.e. by ambulance staff, emergency staff etc), therefore the worst GCS recorded is often used when referring to GCS; and this is the GCS score which has been used for the purposes of this research.

Length of Post Traumatic Amnesia (PTA) is another commonly used criterion for measuring TBI severity; which was first proposed by Russell (1932). PTA is defined as the period from the time of injury until the resumption of continuous memory and includes any period of loss of consciousness or coma (NZGG, 2006; Nakase-Richardson et al., 2009; Ponsford et al., 2004). PTA includes anterograde memory loss for events occurring immediately after the injury and retrograde memory loss for events just before the injury. There are different systems for PTA grading. There have been debates about the definition of PTA, and consequently differing cut off points for categorising or measuring PTA have been proposed and used by different researchers (for a review, see Ahmed, Bierley, Sheikh, & Date, 2000). A commonly used criterion is one proposed by NZGG (2006), where a PTA of seven days or more is considered to be a severe TBI, while a PTA lasting between one to six days is considered a moderate TBI, and a period of PTA less than 24 hours is generally considered a mild TBI. Duration of PTA is positively correlated with the severity of TBI outcomes, with longer PTA associated with more severe outcomes (Manzi & Weaver, 1987; Russell, 1932); being more predictive of outcome than GCS (Nakase-Richardson, et al., 2009) with longer PTA related to reduced likelihood that the patient will return to his/her pre-morbid cognitive functioning (Manzi & Weaver, 1987). There are some limitations with using PTA such as the lack of a universal

definition can lead to different findings; in addition, PTA's reliability is questionable, as often the assessment of PTA is done retrospectively, hence relying on the accuracy of the patient's memory (NZGG, 2006). There are also arguments as to when a patient has recovered from PTA; some believe it is the point of time at which the patient becomes aware of his/her surroundings (Russell, 1932; Russell & Nathan, 1946); while more commonly, it is considered the point where there is a return of continuous memory (Nakase-Richardson, et al., 2009; Petchprapai & Winkelman, 2007; Russell & Nathan, 1946). The assessment of PTA typically involves repeated assessment of the individual each day until such time as he/she shows continuous registration of new memory for 3 days (e.g., Westmead PTA scale, Starship PTA scale) (Fernando, Eaton, Faulkner, Moodley, & Setchell, 2002). Consequently the assessment of PTA is much more time intensive than other methods and it is therefore not always conducted clinically.

Loss of consciousness (LOC) is another commonly used criterion for measuring TBI severity. LOC refers to a lack of awareness or inability to respond to the environment (Petchprapai & Winkelman, 2007). There is evidence that longer periods of LOC are related to poorer outcome, however this is controversial for mild TBI. A study by Lovell, Iverson, Collins, McKeag, and Maroon (1999) failed to find any relationship between LOC and neuropsychological functioning in a large sample of patients with mild TBI during the acute phase, which is when cognitive deficits are most pronounced for this group. There is also variability in the literature concerning the duration of LOC required for the diagnosis of mild TBI, ranging from a brief (less than one minute) LOC up to a minimum of 30 minutes (Alexander, 1995; Ruff & Jurica, 1999). In many mild TBI cases, no LOC occurs; and when there is a LOC, the duration of unconsciousness tends to be short. Hence this criterion is less useful for mild TBI than for more severe TBIs.

As noted above, each of the three criteria has limitations, particularly when used to define mild TBI. Therefore, it is much more common to use a combination of all three, sometimes with other additional criteria added for the diagnosis of mild TBI (McCrea, 2008). The use of multiple severity indicators is intended to improve sensitivity in the detection of mild TBI (McCrea, 2008). Table 1 shows the criteria for the three most commonly used operational definitions for mild TBI in clinical practice and the research literature. As can be seen in Table 1, there is a large amount of overlap between the definitions proposed by the WHO (NZGG, 2006), the American Congress of Rehabilitation Medicine (ACRM) (Kay et al., 1993), and the Centers for Disease Control and Prevention (CDC) (2003).

Table 1

Varying criteria for mild TBI definitions

Criteria	GCS	PTA (hours)	LOC (minutes)	Neurological symptoms
WHO (NZGG, 2006)	13-15 Confusion or disorientation	< 24	< 30	Focal neurological abnormalities, seizure and/or intracranial lesion
ACRM (Kay, et al., 1993) (One or more of these criteria)	13-15	< 24	< 30	Focal neurological deficit(s) that may or may not be transient
CDC(One or more of these criteria)	NA	≤ 24	< 30	Any Neurological or neuropsychological dysfunction supplemental to LOC/PTA

WHO: World Health Organization; ACRM: American Congress of Rehabilitation Medicine; CDC: Centers for Disease Control.
GCS: Glasgow Coma Scale; PTA: post traumatic amnesia; LOC: loss of consciousness

As seen in Table 1, all three definitions require a change in consciousness and memory for a diagnosis of mild TBI. Other definitions used by researchers in the field however, have placed varied emphasis on acute injury characteristics. One of the problems with mild TBI research is that cut-off points for the diagnosis are often vaguely defined and different limits have been used (Kibby & Long, 1996). Another source of confusion with mild TBI epidemiologic studies is the fact that acute signs and symptoms resolve rapidly, hence the symptoms may not be detected if

the patient does not seek immediate medical attention leading to under-diagnosing mild TBI. Unlike moderate and severe TBI, mild TBI cannot be reliably identified by neuroimaging (Ruff, Iverson, Barth, Bush, & Broshek, 2009). Another confusion is that various terms have been used interchangeably when referring to mild TBI, including mild brain injury, mild head injury, minor head injury, minor head trauma and concussion (National Center for Injury Prevention and Control, 2003; Petchprapai & Winkelman, 2007).

The WHO Collaborating Centre Task Force on Mild Traumatic Brain Injury critically reviewed the literature on mild TBI published between 1980 and 2002 (Carroll, Cassidy, Holm, Kraus, & Coronado, 2004). They noted that there is a large amount of literature published on this topic; however they are of variable quality. Out of 743 relevant studies on mild TBI, only 313 studies met their inclusion criteria of being considered methodologically sound in order to be included in their report, 32% of the accepted studies were specifically on the diagnosis of mild TBI. A major issue they noted was that a wide range of conditions are considered to comprise mild TBI and there was considerable heterogeneity in the case definitions used by researchers. For example, of the 313 studies included, 62% incorporated the GCS into their case definition; with some including GCS of 13 to 15, some only accepting GCS of 14 or 15, and others considered only a GCS of 15. Further, only some definitions required LOC and/or PTA, and again the duration of these varied; and some studies also required the presence of focal neurological abnormalities. The 38% of studies that did not utilise GCS in their criteria used either LOC and/or PTA. To date, while there is no universally accepted definition of mild TBI, the WHO Task Force recommended a specific definition for this type of injury; as follows:

"*MTBI is an acute brain injury resulting from mechanical energy to the head from external physical forces. Operational criteria for clinical identification include: (i) 1 or more of the following: confusion or disorientation, loss of consciousness for 30 minutes or less, post-traumatic amnesia for less than 24 hours, and/or other transient neurological abnormalities such as focal signs, seizure, and intracranial lesion not requiring surgery; (ii) Glasgow Coma Scale score of 13–15 after 30 minutes post-injury or later upon presentation for healthcare. These manifestations of MTBI 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, p. 115)"

The current study used the WHO definition of mild TBI for two main reasons. First, this definition was formed after critically reviewing mild TBI definitions used in the current literature, and is generally consistent with the three most commonly used definitions (see Table 1). This will therefore allow comparisons of the findings to a greater number of published studies. Secondly, this definition was acknowledged by the NZGG as the best available to date and is the accepted definition for use in NZ where the present study is based. However, as noted in the above discussion, there are limitations to the existing criterion for mild TBI. Specifically, there appear to be ceiling effects associated with the GCS, and many who sustain a mild TBI will experience no LOC or PTA (McCrea, 2008). Each of these can result in difficulty with differentiating those within the milder end of the mild TBI range. Differentiation of the mild TBI category into more discrete ranges has been suggested because of the need to better predict

those who are likely to experience ongoing difficulties after mild TBI (discussed in more detail in Chapter II).

Sub-classification of Mild TBI

Williams, Levin, and Eisenberg (1990) divided mild TBI, as defined by GCS scores into "complicated" and "uncomplicated" groups based on radiological findings. "Uncomplicated" mild TBI were those with a normal CT scan, and either a normal skull x-ray film or an abnormality limited to a linear or basilar skull fracture, while "Complicated" mild TBI referred to those with skull fractures and/or intracranial abnormalities. These researchers evaluated a sample of 215 patients with mild to moderate TBI (GCS of 9 to 15) using the Glasgow Outcome Scale score taken six months post injury. They found that those with an "uncomplicated" mild TBI had better functional outcome compared to those with "complicated" mild TBI and moderate TBI. Furthermore, the functional outcome of the "complicated" mild TBI group was more similar to the moderate TBI group.

Likewise, Hsiang, Yeung, and Yu (1997) proposed mild TBI be sub-grouped based on GCS score and CT findings. They analysed a group of 1,360 patients with mild TBI (GCS range 13 to 15). They found that patients with lower GCS scores tended to have suffered more serious injury. They proposed low risk mild TBI be defined as a GCS score of 15, without acute radiographic abnormalities; while high-risk TBI was defined as those with GCS scores of 13 or 14, or a GCS score of 15 with acute radiographic abnormalities.

More recently, Servadei, Teasdale and Merry (2001) proposed that mild TBI be divided into mild "low risk", "medium risk" and "high risk" head injury groups. As can be seen in Table 2, only those with a GCS of 14 and 15 are defined as having an acute mild TBI in this system;

while those with a GCS score of 13 are omitted as their risk of intracranial lesions is similar to that of patients with moderate TBI. Other criteria include clinical findings, neurological deficits, skull fracture and risk factors.

Table 2

Categories for level of risk for negative outcomes after mild TBI (Servadei, et al., 2001)

Risk	Glasgow Coma Score	Clinical findings*	Neurological deficits	Skull fracture	Risk factors**
Low	15	Absent	Absent	Absent	Absent
Medium	15	Present	Absent	Absent	Absent
High	14	May or not be associated with other clinical or radiological findings.			
High	15	Present/absent	Present	Absent	Absent
High	15	Present/absent	Absent	Present	Absent
High	15	Present/absent	Absent	Absent	Present

*One or more loss of consciousness, amnesia, vomiting, and diffuse headache.
**Coagulopathy, drug or alcohol consumption, previous neurosurgical procedures, pre-trauma epilepsy, and age over 60 years.

Despite the availability of these varying degrees of risk within the mild TBI category, research has not yet determined their ability to predict mild TBI outcomes. Accomplishing this, with reference to the most recent categorization proposal by Servadei, et al. (2001) was one of the aims of the present study. Having now reviewed definitions of TBI, including some of the systems for differentiation of categories of risk within the mild TBI group, the section which follows examines the epidemiology of TBI, with a focus on mild TBI. This includes a discussion of some of the methodological issues carrying out population-based studies in TBI.

Epidemiology of TBI

The following section covers information on the incidence and prevalence of TBI with a focus on mild TBI. This is followed by a review of mechanisms, underlying pathology, and economic burden of mild TBI.

TBI is a major public health concern; disrupting the life of the individual, family, friends and the wider community. A large proportion of TBIs, between 70 and 90% fall in the mild category (Cassidy, et al., 2004), while moderate TBI account for approximately 5% to 20%, and the remaining 5% to 20% are severe TBIs (Ryu, Feistein, Colantonio, Streiner, & Dawson, 2009). Goldstein (1990) termed mild TBI as a "silent epidemic", and was also referred to by the CDC in its' report to the U.S. Congress in 2003 by this term, based on concerns that the true incidence and outcome of mild TBI is underestimated (cited in McCrea, 2008).

In the United Kingdom, Australia and North America between 200-300 people per 100,000 are admitted to hospital with a TBI (of all severity) annually (Torner & Schootman, 1996). Similar rates have been reported in NZ. For example, Barker-Collo, Wilde and Feigin (2009) examined the incidence of hospital admissions for TBI in NZ using a national health database.

The overall incidence reported was 226.9 per 100,000 in 1998/1999, with a higher rate of 349.2 per 100,000 in 2002/2003 (Barker-Collo, et al., 2009). It is of note that during this time, the International Classification of Disease, 9th revision (ICD-9) was replaced by ICD-10. The ICD-9 code for head injury had more stringent criteria such that it did not include concussion unlike ICD-10.

The WHO Collaborating Centre Task Force on Mild Traumatic Brain Injury (2004) reported that the incidence of hospital-treated mild TBI is between 100 to 300 cases per 100,000 populations annually. However, the researchers point out that this figure is still an underestimate of the true incidence of mild TBI (Cassidy, et al., 2004). This is partly due to variable case definitions and heterogeneous research methods. Bazarian et al. (2005) reported a much higher incidence rate of 503 per 100,000 for emergency department attended mild TBI cases, including those who were not admitted or hospitalised. They carried out a secondary analysis of emergency department visits of the National Hospital Ambulatory Medical Care Survey (NHAMCS) for the years 1998–2000. Patients meeting the ICD-9 definition of mild TBI during these years were analysed. NHAMCS is a multi-stage probability sample of 25,000 emergency department visits collected each year by the CDC and the National Center for Health Statistics. This higher incidence reflects a central difficulty in studying mild TBI. While capturing moderate and severe TBIs is straightforward as the majority of these patients are hospitalised, in contrast, most mild TBI cases are not hospitalised, with a minority seeking medical attention (Sosin, Sniezek, & Thurman, 1996).

Two U.S. national surveys revealed that a high proportion of this population do not seek medical treatment after a TBI and up to 25% are not admitted to the hospital (Fife, 1987; Sosin, et al., 1996). A survey of mild and moderate TBI patients by Sosin, Sniezek, and Thurman

(1996) found that 25% the sample did not seek any medical attention, while 14% were treated in community clinics, 35% treated in emergency departments and 25% hospitalised, indicating up to 75% seeking some sort of medical treatment. Another study reported a lower rate of only 16% TBI patients were hospitalised (Fife, 1987). In the past two decades, fewer mild and moderate TBI cases are admitted to hospital, with more attended to by emergency departments and other outpatient settings (McCrea, 2008). Hence capturing mild TBI is a growing challenge (Ryu, et al., 2009), and mild TBI in particular thought to be underestimated (McCrea, 2008). While many epidemiology studies only include patients who are hospitalised, others include patients treated and released from hospital emergency departments and general practices in an attempt to produce a more accurate incidence rate. For example, Ryu et al. (2009) reviewed both emergency department (ED) and family doctor practice records using the ICD-9) codes to identify mild TBI cases. Based on ED records alone, they reported an incidence rate of 535 per 100,000 for mild TBI alone. The incidence rate went up to 653 per 100,000 when they included cases identified through family doctor practices records. According to the WHO Collaborating Centre Task Force on Mild Traumatic Brain Injury the true incidence of mild TBI is likely to be over 600 per 100,000 (Cassidy, et al., 2004). While in NZ the population-based rate for mild TBI is unknown, but it is estimated to be as high as 660 per 100,000 per year (NZ Guidelines Group, 2006). This translates to 20,000-30,000 mild TBIs cases a year (Barker-Collo, et al., 2009).

To accurately capture incidence rates, population based studies should be used. To date, there has only been one published population-based study of the incidence of TBI, which was conducted in the U.S (Annegers, Grabow, Kurland, & Laws, 1980). Unlike previous studies which identified cases via hospital admission records, and/or death records, and/or general

practitioner (GP) practice records, cases were ascertained through medical records including hospital admissions, accident and emergency, outpatient records, home visits, and death and autopsy reports from Olmsted County from 1935 to 1974. They reported that the incidence rate of TBI of all severities was 270 per 100,000 among males and 116 per 100,000 among females; while the incidence of mild TBI was 149 per 100 000 amongst males and 71 amongst females. This is considerably lower than what has been reported recently, and is likely still not a true reflection of the incidence of mild TBI as it does not include those who did not seek medical help for their injury. Furthermore, this study is based on data that is at least three decades ago, where there was less awareness of TBI, hence patients were even less likely to seek medical attention.

However, as in the case of all TBI, higher rates of mild TBI are reported among young males and minorities (McCrea, 2008). There is general consensus with international research, that the incidence rates of mild TBI for males are almost double that of females. The highest reported incidence rate is for males between 15 to 25 years, and those over 75 years for females (McCrea, 2008; Sosin, et al., 1996), a bimodal age specific incidence rates in the adult population (Bruns & Hauser, 2003a). Similar trends are reported in NZ by the Accident Compensation Corporation (ACC). ACC was set up by the NZ Government to provide no-fault personal injury insurance cover for the country's citizens, residents and temporary visitors. ACC figures showed that the highest rate of mild TBI occurred in those aged between 15 to 19 years of age (Larkin, 2004). According to the 2003 ACC figures, 61.9% of patients with mild TBI were male, which approximates international data suggesting a roughly 2:1 ratio for males:females with TBI (Larkin, 2004); a finding replicated by Barker-Collo, Wilde and Feigin (2009) who also noted disparity in hospital based incidence rates according to age, and ethnicity. ACC figures showed that of those with mild TBI, 14% identified as NZ Māori, and 5% as Pacific

Islander people (Larkin, 2004). The incidence rates for Māori (indigenous people of NZ) males and females were 689 and 302.8 per 100,000 person-years, respectively; and Pacific Island males and females were 582.6 and 217.6 per 100,000 person years, respectively. These are much higher rates than those for the total NZ males and females with incidence rates of 435.4 and 200.9 per 100,000 person-years. Thus, the incidence rates for ethnic minorities in NZ of both genders exceeded those for the total population (Barker-Collo, et al., 2009). Higher incidences of TBI have also been linked to lower socio-economic status and urbanisation (Bruns & Hauser, 2003a, 2003b; Chiu et al., 1997), alcohol abuse and lower educational levels (Barnfield & Leathem, 1998).

Mechanisms of mild TBI

As can be seen in Table 3, the most commonly reported cause of mild TBI is motor vehicle accidents (MVA), accounting for up to 50% of all mild TBIs in most studies; followed by falls, ranging from 10% to almost 30%; and assaults, up to 15%. Other causes include sports or recreational activities, falling objects, motor vehicle versus pedestrian, and suicide.

Table 3

Summary of causes of mild TBI by different studies

	Jacobs et al. (2010)	Hanon, et al., (1999)	Kraus & Nourjah (1988)	Alves, Macciocch & Barth (1993)
Participants (n)	2784 mild TBI patients admitted to	100 mild TBI patients from an outpatient concussion clinic	2754 mild TBI cases hospitalised in	587 uncomplicated

	emergency department		San Diego County	hospitalised mild TBI cases
Mechanisms		Percentages (%)		
MVA	55	61	42	53
Falls	29	11	23	17
Assaults	8	10	14	15
Falling object	-	10	-	2
Sports/recreational activities	6	5	12	-
Motor vehicle versus pedestrian	-	3	-	8
Unspecified	2	-	8	5
Suicide	1	-	-	-

MVA=Motor Vehicle Accidents

Neuropathology of TBI

In order to understand the consequences of mild TBI, the neuropathology of TBI should be considered first. Most commonly, TBI occurs when the head suddenly accelerates, decelerates or rotates within the skull (Ogden, 2005). The damage occurs in three stages, resulting in the first, second and third injury (Gronwall, et al., 1990). The damage to the brain is caused by the movement of the soft brain mass inside the bony skull with the first injury occurring in the first couple of seconds. This is also referred to as impact damage, which results in two types of injuries, contusions and diffuse axonal injuries (DAI). Cortical contusions and lacerations may occur beneath (coup) or opposite (contre-coup) the site of impact (Lindsay & Bone, 1998) (see Figure 1). This is caused by the rubbing of the brain surface against the sharp ridges and edges inside the skull. Coup injuries refer to focal injuries that occur when the brain hits the skull on impact, the damage is at the site of the impact. Contre-coup injuries is a result of the brain hitting the skull opposite the point of impact as brain moves inside the skull (Ogden, 2005). There are billions of nerve cells located in the gray matter within the brain (Igou, 2001). These nerve cells communicate with distant nerve cells through long nerve fibers called axons, composing the white matter (Igou, 2001). As the brain vibrates, the fibers are damaged through being stretched, twisted, and sheared following deceleration resulting in diffuse damage to the nerve fibers, or DAI (Lindsay & Bone, 1998). DAI causes microscopic damage to the brain, and mild TBI is often linked to a milder type of DAI (Sivák, Kurča, Jančovič, Petriščák, & Kučera, 2005), although DAI can range from very mild to moderate and very severe damage (Smith & Meaney, 2000). Arteries and veins may also be torn, leaking blood into brain tissues and causing diffuse disruption to the brain and sometimes resulting in large areas of focal damage. Unlike moderate and severe TBI, where damage to the brain can be detected on conventional

neuroimaging such as computed tomography (CT) or magnetic resonance imaging (MRI) scans, there are often no detectable abnormalities of the brain for mild TBI (Igou, 2001; Inglese et al., 2005). This presents an inherent challenge in applying neuroimaging to diagnose mild TBI and predict outcomes for these patients (Mechtler, Shastri, & Crutchfield, 2014). Fortunately, advanced imaging tools such as diffusion weighted imaging (DWI) and diffusion tensor imaging (DTI), a special type of MRI sequence have been developed (Shenton et al., 2012). They have the ability to detect microscopic white matter damage and trace specific tracts of the brain; and are the best imaging techniques available for detecting white matter integrity/damage at present (Shenton, et al., 2012). This is an important step where mild TBI diagnosis can be based on radiological evidence, rather than symptoms alone. They have the added advantage of detecting and localising of brain alterations in mild TBI. They may be potential prognostic measures for evaluating the extent of brain injuries and identify those who are likely to recover versus those who experience prolonged symptoms (Inglese, et al., 2005; Shenton, et al., 2012).

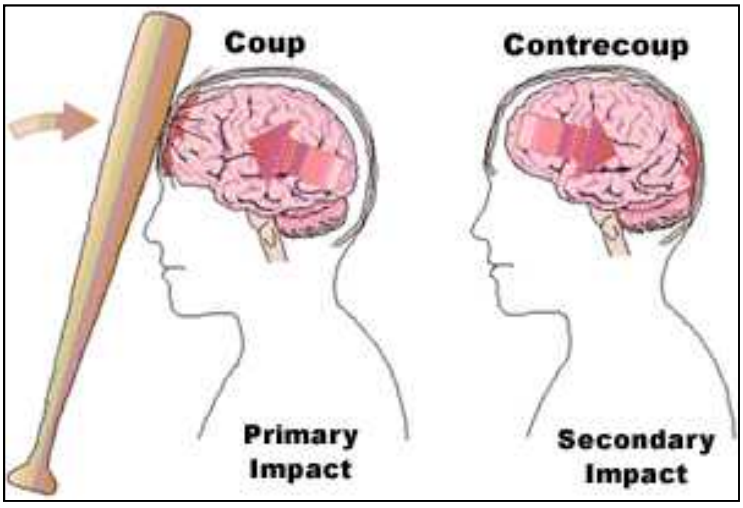

Figure 1. Coup and contrecoup injury (Igou, 2001)

Apart from the first injury, sometimes there is a second injury which occurs within the first hour. This occurs if the patient is trapped and his/her breathing is blocked, which reduces oxygen supply to the brain (Ogden, 2005). The brain is susceptible to damage through lack of oxygen (hypoxia) (Igou, 2001). If there is a loss of a significant amount of blood, lowering of blood pressure and a reduction in the supply of blood and oxygen to the brain may lead to other injuries (Ogden, 2005).

Occasionally a third injury occurs days or weeks (up to a month) after the initial injury, this is more common for severe TBIs (Ogden, 2005). The third injury often leads to a worsening of the patient's condition or even become fatal (Ogden, 2005). These complications include bruising and swelling of the brain, blood clots, chronic subdural haematoma and post-traumatic hydrocephalus (Gronwall, et al., 1990). Swelling or edema of the brain becomes dangerous when it causes a rise in intracranial pressure (ICP) which prevents blood from entering the skull to deliver glucose and oxygen to the brain. Hematoma is a collection of blood due to tissue injury or the tearing of a blood vessel. There are three different types of blood clots; epidural hematoma develops outside the dura, between the skull and dura; subdural hematoma develops between dura and the brain; while blood leaking into the cerebrospinal fluid is known as a sub-arachnoid hemorrhage. When blood gets into the cerebrospinal fluid and blocks the spinal fluid absorption sites, spinal fluid may back up into the ventricles, enlarging the ventricle, this condition is known as hydrocephalus (Igou, 2001).

Although in most cases of mild TBI, patients are unlikely to develop all these injuries, it is not unlikely that some of these patients will experience some of above. Some symptoms are more common in mild TBI than others, such as DAI (as discussed above). Despite the fact that

the majority of mild TBI patients do not seek medical attention, mild TBI has been shown to result in economic burden for society.

Costs of mild TBI

The exact economic burden associated with mild TBI is difficult to evaluate since this is dependent on the incidence rate, which is variable due to methodological issues (Ryu, 2008), and thought to be underestimated as noted above. Based on an annual incidence of 130 per 100,000 in the U.S., Klaus et al. (1984) estimated the cost to be U.S.$1 billion in 1981. When a mild TBI incidence rate of 440 per 100,000 is assumed (Jager, Weiss, Coben, & Pepe, 2000), the estimated cost of emergency care alone is thought to be U.S. $346 million. In NZ, annual estimated direct costs of TBI range from $69 million to $103 million (Barker-Collo & Feigin, 2008). In 2004, ACC figures in NZ showed that they paid over NZ$100 million a year for post-acute treatment and rehabilitation of claimants with concussion and TBI (Larkin, 2004). This figure does not include costs for acute care. In 2003, a total 17,514 new cases of concussions were lodged, leading to claim payments of $12,532,834 for the year of 2002 (Larkin, 2004).

Beyond health care utilisation costs, even less is known about cost associated with lost work time and productivity. For example, Englander, Hall, Stimpson, and Chaffin, (1992b) examined the return to work rate based on 77 insured patients following mild TBI and found that 88% had returned to their former job or school eight weeks post injury. Powell, Collin, and Sutton (1996) reported a higher return to work rate of 95% based on a sample of 65 mild TBI patients. However, this sample may not be representative of the mild TBI population. They excluded patients with significant neuropsychiatric problems, such as drink, drugs and previous

head injury, which constitute the “complicated mild TBI” group. Both studies (T. Powell, et al., 1996) had small samples, therefore its’ generalisability to mild TBI population is questionable.

In summary, although the exact incidence rate of mild TBI is unknown, most researchers believe mild TBI affects a large proportion of the population. A number of problems can develop following this seemingly “mild” injury. The following section will examine short term outcomes of mild TBI.

CHAPTER II: SHORT TERM OUTCOMES OF MILD TBI

This section reviews the various ways in which health outcomes have been conceptualized. The focus is on the development and limitations of the International Classification of Impairments, Disabilities and Handicaps (ICIDH; WHO, 1980) and its replacement the International Classification of Functioning, Disability and Health (ICF; WHO, 2001). This is followed by a review of the research examining short term neuropsychological and functional outcomes in patients with mild TBI. This includes a review of the literature relating to body structure and impairments, including physical impairments, cognitive, and emotional outcomes. The final section will look at short term functional outcomes namely activity and participation of mild TBI survivors.

Models of health outcomes

A number of models of human functioning and disability have been applied in the context of health outcomes (e.g., bio-medical model, social model, psychosocial model). The bio-medical model assumes health as the absence of diseases (Wade & Halligan, 2004). This model focuses on abnormality of the biological systems (e.g., pathology, biochemistry and physiology) as the cause of diseases leading to ill health (Engel, 1977). It assumes that illness has a single underlying cause (the disease) and the removal of the disease will lead to good health (Wade & Halligan, 2004). Hence the role of the health professional is to remove the disease from the patient and relieve the associated symptoms generated by the disease (Bickenbach, Chatterji, Badley, & Ustun, 1999). This model sees the patient as having minimal responsibility for the development and course of the disease. The patient is a passive recipient of treatment, although some cooperation is required (Wade & Halligan, 2004). This model is criticised for its over-

emphasis of the medical condition and lack of consideration for the impact of psychological and social factors (Engel, 1977).

The social model on the other hand proposes that disability is caused by society through systemic barriers (e.g., negative attitudes, lack of resources and un-accommodating physical environment) (Jette, 2006). This model recognizes that some individuals have physical or psychological conditions which may cause them functional limitations or impairments. However, these do not lead to a disability unless society fails to accommodate the individual's needs (Wade & Halligan, 2004). A limitation of this model is that even though society plays an important role in peoples' lives, there is an overemphasis on the impact of social factors.

Both the bio-medical and social models capture aspects of the patient's life, however biology and society are entwined (Imrie, 2004). The bio-psycho-social model combines the medical and social models of disability. It takes a holistic approach and views disability as an interaction between biological, psychological (e.g., thoughts, emotions and behaviours) and social factors (Engel, 1977). In this model, 'biological' refers to physical or mental health conditions, while 'psychological' refers to the personal or psychological factors that influence functioning, and 'social' refers to the impact of socio-cultural environment on illness behaviour. Although this model represents the dominant perspective behind contemporary models of disability, some argue it separates biology and psychology, creating an arbitrary distinctions between organic and nonorganic factors (Tavakoli, 2009).

The next section discusses how the World Health Organization's models address the various issues raised, with a focus on their latest proposed bio-psychosocial model.

WHO Models of Health Outcomes

The WHO recognized that while the medical model and its associated International Classification of Diseases (ICD) was useful for classifying medical diagnoses, yet functional status of the patient is neglected. Also, it was inadequate for rehabilitation as it did not address the consequences of chronic diseases (Fougeyrollas, 1995; Stucki, Cieza, & Melvin, 2007). Thus, the WHO developed the International Classification of Impairments, Disabilities, and Handicaps (ICIDH) 'for trial purposes' for use in conjunction with the ICD (WHO, 1980). The main aim of the ICIDH was to clarify confusions in terminology and present a cause and effect relationship between conceptual levels. According to this model, injury/disease leads to functional and organic impairment, which in turn results in disability in an individual's behaviour and activities, which generates handicaps and disadvantages, with respect to roles (WHO, 1980). "An impairment is any loss or abnormality of psychological, physiological, or anatomical structure or function" (WHO, 1980, p. 27) and is associated with 'signs and symptoms'. In contrast, "a disability is any restriction or lack (resulting from an impairment) of ability to perform an activity in the manner or within the range considered normal for a human being" (WHO, 1980, p. 28). Finally, "a handicap is a disadvantage for a given individual, resulting from an impairment or a disability, that limits or prevents the fulfilment of a role that is normal (depending on age, sex, and social and cultural factors) for that individual" (WHO, 1980, p. 29). Thus, handicap is a result of impairments and disabilities and is seen within the social context where an individual is placed at a disadvantage in relation to his peers.

The ICIDH is a unifying framework for classifying function and disability associated with health conditions and has been widely use for a variety of purposes including health outcomes research and social policy development (Bickenbach, et al., 1999). However, it was not

approved as an official WHO classification (Cieza & Stucki, 2008). The linearity of the model as it progressed from biomedical to psychosocial constructs (i.e., from impairments to disabilities to handicaps) was criticised as the model views functioning as a consequence of a disease (Stucki & Cieza, 2004). Furthermore, the model was criticised for its use of negative terminology (Cieza & Stucki, 2008). Another limitation is that it did not clarify the causal and temporal relationship between the three dimensions (Fougeyrollas, 1995). The three constructs also lacked clarity with overlap between impairment and disability dimensions, and between the disability and handicap dimensions (Badley, 1993). Finally, the ICIDH did not explicitly recognize the role of the environment on an individual's experience of a health condition (Cieza & Stucki, 2008; Fougeyrollas, 1995; Stucki, et al., 2007).

Consequently, the WHO developed the International Classification of Functioning, Disability and Health (ICF) to address the criticisms of the ICIDH. The ICF is a framework used to measure health and disability at both an individual and population levels. This model was endorsed by the WHO in 2001. Functioning is seen as a result of the interaction between the health condition and environmental influences (Stucki & Cieza, 2004; Stucki, et al., 2007). The dimensions are interactive and dynamic rather than linear or static. It provides a framework with a unified and standardized language for classifying and describing health and health related domains (Cieza & Stucki, 2008). The ICF was approved by the 54th World Health Assembly in May 2001 (WHO, 2001).

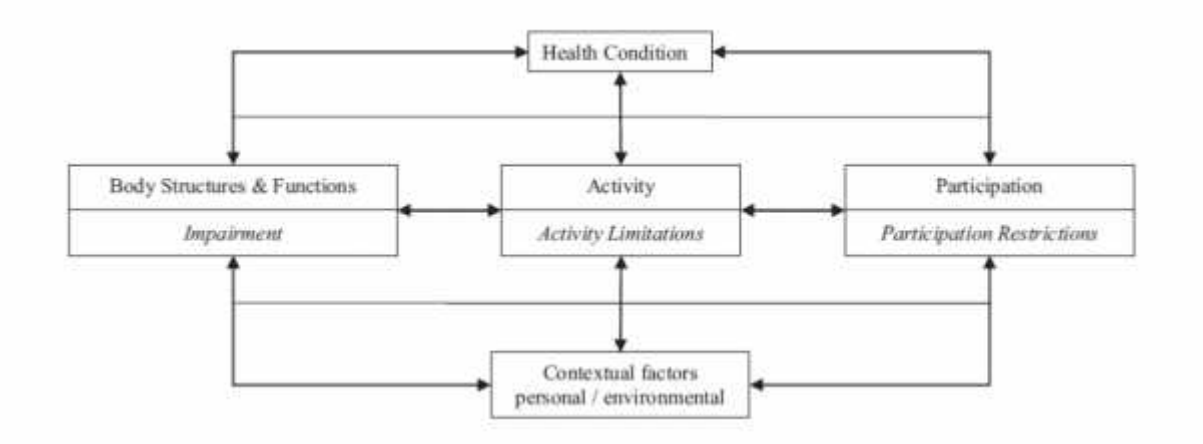

Figure 2. The current framework of Functioning, Disability and Health (ICF)

The ICF model (Figure 2) is based on the bio-psycho-social model, it is a recent and comprehensive model of functioning and disability (Stucki, et al., 2007). Functioning encompasses three central concepts body functions and structures, activity and participation. It also recognizes the role of contextual factors (personal and environmental). In this model 'functioning' denotes positive aspects of the condition and 'impairment' is complementary to 'functioning', and denotes negative outcomes (Stucki, et al., 2007). The concepts of activity limitations and participation restrictions replace the concepts of disability and handicap (Dixon, Johnston, Rowley, & Pollard, 2008).

'Body functions' are the physiological and psychological functions of the body systems (e.g., muscle weakness, processing speed), while 'body structures' refers to the anatomical parts of the body (e.g., lobes of the brain, limbs). Any abnormality in body functions or structures is referred to as 'impairment', meaning a significant deviation or loss of structures and/or functions. In contrast, 'activity' is the execution of a task by the individual, including his/her capacity to carry out the task and actual performance of the task in his daily life. It also includes the individual's subjective perception of functioning. Difficulties executing activities

are referred as 'activity limitation'. Finally, 'participation' refers to involvement in life situations. It represents the social perspective of functioning. Problems experienced by an individual with such involvements are called 'participation restriction' (e.g. inability to participate in paid employment).

'Environmental factors' include physical, social and attitudinal environment such as products and technology, supports, relationships, attitudes, available services, social systems and policies which can facilitate or hinder an individual's level of function and disability. 'Personal factors' refers to the individual's background but do not include his health condition (e.g., age, sex, race, health conditions, fitness, habits, coping style).

Thus, the focus of the ICF is on activities of an individual and his participation and contribution to the social environment. All aspects of the individual's life are incorporated into the ICF instead of solely focusing on his or her diagnosis. It integrates the medical and social aspects of the individual's health condition. The ICF framework is comprehensive, with universally accepted terminology for functioning and disability and has been implemented in many countries in various sectors. To improve clinical applicability, ICF Core Sets were developed to serve as a reference framework and a means of classifying and describing functioning in a more time efficient way. However it contains more than 1400 categories, which limits its use in clinical practice (Aiachini et al., 2010). . Unfortunately, at the time of this study, an ICF Core Set for TBI was not yet available; as it was undergoing extensive testing and validation (Stucki & Cieza, 2004). The most common problems following TBI using the ICF were examined in a cross-sectional empirical study described the functioning and health of 261 TBI patients in Italy (Aiachini, et al., 2010). The findings indicated that the most common problems were in the domains of body functions, and activity and participation. Therefore, it is

important to use a comprehensive perspective including body functions and structures, activities and participation and environmental factors in describing outcomes for TBI patients. Hence the ICF is an appropriate framework for the present study.

Having reviewed various models of health and with particular attention to the ICF, which was the base framework for the present study, the following sections are going to look at mild TBI short term outcomes using this framework.

Importance of studying short term outcomes

The diagnosis of mild TBI is often overlooked, yet despite the term "mild", these injuries can result in ongoing difficulties. Many patients with mild TBI do not receive medical care or rehabilitative services (Petchprapai & Winkelman, 2007). Frustration with unrecognized mild TBI related disability and lack of appropriate treatment may adversely influence social and physical functioning, disrupt family life, lead to emotional difficulties, affecting the patient's overall health and wellbeing (Petchprapai & Winkelman, 2007). According to Iverson (Iverson, 2005, 2006), the patient typically experiences maximal symptoms and problems within the first 72 hours of injury with rapid improvements in functioning over the next ten days. More specifically, an estimated 50% of patients with mild TBI have symptoms that tend to resolve within a few days to several weeks following the TBI (Evans, 1992). The number and severity of the symptoms experienced varies widely across individuals. Fortunately, most make full recovery within the first three months post-injury (Iverson, 2005; Levin et al., 1987). King (2003) reports about 75% of patients are symptom free by three months. While in some, symptoms may remain for three to six months (Evans, 1992). Approximately 80% to 90% recover by six to 12 months (Silver, McAllister, & Arciniegas, 2009). However, by 12 months,

between 5% to 15% still experience some residual symptoms (Iverson, 2005; King, 2003). These individuals have been referred to as the "miserable minority" by Ruff (1996, 2005), where they experience symptoms with cognition, emotion and behaviour (Silver, et al., 2009). These symptoms are commonly referred to as post concussive symptoms. If the individual is experiencing a cluster of post concussive symptoms, he or she may meet criteria for Post Concussive Syndrome (PCS), "a condition arising after 'head injury' that produces deficits in three areas of CNS functioning: 1) somatic, 2) psychological, and 3) cognitive" (Hall, Hall, & Chapman, p. 196). Short term outcome of mild TBI is particularly important as knowledge in this area will assist in the management of this injury; and it is believed that good management of the symptoms in the early stages may prevent or reduce long term complications, therefore reducing the likelihood of patients developing PCS, and socioeconomic costs associated with mild TBI. Patients diagnosed with PCS may present with very different symptoms, although the term PCS is a convenient label for communicating with patients and health professionals (Anderson, Heitger, & Macleod, 2006), it is more appropriate to examine the post concussive symptoms on their own as treatment needs to be tailored to the particular symptom. Therefore, the following sections will, after examining risk factors for PCS, examine common symptoms within each of the three areas of the ICF separately.

Risk factors for post concussive symptoms

A number of potential risk factors have been identified for the development of PCS, including the number of and severity of post concussive symptoms. These include demographic variables (e.g., female gender, older age, low socio-economic status), psychosocial (e.g., unstable relationships, lack of social support network, pre-existing psychiatric problems or personality

disorder, chemical dependency), medical (e.g., severe associated injuries, co-morbid medical or neurologic disorders, prior history of mild TBI, alcohol abuse), and situational (e.g., litigation/compensation, concurrent posttraumatic stress disorder, intoxication at the time of injury) (Alexander, 1995; Carroll et al., 2004). Some authors have looked at the injury characteristics, such as severity of the mild TBI, and have found that those with complicated mild TBI who have focal, structural damage detected on CT or MRI are at risk of slower recovery with prolonged symptoms and poorer overall outcome similar to moderate TBI (Iverson, 2006; McCrea, 2008), however, some patients who suffer an uncomplicated mild TBI also experience prolonged symptoms.

Body Functioning and Structure Impairments

The "body functions and structural impairments" in the ICF denotes neurological/somatic as well as the psychological and cognitive outcomes that are characteristic of PCS. These are each reviewed below, followed by an examination of areas of activity and participation that are noted to be impacted following a mild TBI.

Physical and Sensory outcomes

One of the most common somatic or physical symptom following mild TBI is headaches (Hall, et al., 2005). Headaches may last longer and occur more frequently compared to headaches experienced pre-injury, and it is not uncommon for these headaches to occur for up to two to three weeks post-injury (Anderson, et al., 2006). Of those treated for PCS, between 30% to 90% report more frequent headaches post-injury, and between 8% and 32% continues to report them one year post-injury (Hall, et al., 2005). Dizziness is the another common physical

problem reported, with nearly 25% of those diagnosed with PCS reporting the presence of dizziness one year post-injury (Hall, et al., 2005). Older patients are at higher risk of developing dizziness post mild TBI. In a different study by Kashluba, Hanks, Casey, and Millis (2008), found that fatigue was the most frequently reported symptom, followed by headaches (58%). The Problem Checklist was administered on 110 mild TBI patients at 30 and 100 day post-injury. Fatigue is another huge problem post mild TBI. Norrie et al. (2010) examined fatigue prevalence through a prospective study of 263 adults with mild TBI. A high prevalence of fatigue was reported initially, which reduced over time; 68%, 38% and 34% at one week, three and six months post injury. Sensory deficits are also common post mild TBI, such as light and noise sensitivity (10%), decreased sense of taste or smell (5%), and blurred vision (15%) (Hall, et al., 2005). Other less common visual complaints include double vision, difficulties focusing, or diplopia (Anderson, et al., 2006). Sometimes patients report hearing difficulties such as tinnitus or loss of hearing (Cobb & Battin, 2004). Sleep may also be disrupted, insomnia, sleepiness or fatigue are not uncommon (Margulies, 2000). These physical symptoms usually resolve spontaneously without treatment (Anderson, et al., 2006). The literature regarding causes of sensory deficits is inconclusive, some suggest that they may represent either peripheral or perhaps more likely central vestibular pathway dysfunction (Anderson, et al., 2006).

Cognitive outcomes or deficits

Cognitive deficits are commonly reported post mild TBI, and these frequently include confusion or impaired cognition; problems with attention; impaired judgment; memory problems; especially short-term memory; slowed information processing; and difficulty with abstract thinking and problem solving (Hall, et al., 2005; Kibby & Long, 1996). Even those who

claim to be fully recovered from the mild TBI may continue to experience a reduction in their mental efficiency when under stress (Chaudhury, Biswas, & Kumar, 2013).

Levin, et al. (1987) compared 57 "minor head injury" patients who were admitted to three different medical centres with 56 controls, who were assessed at one week and one month post-injury using tests of memory, attention and information processing. They found that nearly all participants tested at baseline showed disturbances of attention, memory and information processing in the first few days post mild TBI, however these symptoms had substantially resolved by three months post-injury, as indicated by mild TBI patients exhibiting test results within the range of matched controls. The researchers acknowledged the bias in generalising this finding, as they could not rule out pre-existing differences in cognitive ability between the two samples.

Unlike Levin, et al.'s (1987), Lidvall, Linderoth, and Norlin (1974) compared mild TBI patients with and without PCS, and found no difference between the two. The participants' performance on several measures of cognitive functioning was compared at 2, 6, 14, and 30 days post-injury. Although the results from this study have found no differences within mild TBI patients, such findings are difficult to compare with other studies given it does not have a control sample. However, it is interesting that there was no difference in cognitive functioning between the two groups, given PCS includes cognitive deficits.

In another study by Newcombe, Rabbitt, and Briggs (1994), who compared 20 hospitalized "minor head injury" patients to 20 hospitalized control patients with orthopaedic injuries or "minor operations" and found no evidence of a significant and overall decrement in performance on cognitive tests within 48 hours post-injury. The participants were assessed on a story recall

task, a card-sorting task, a modified version of the PASAT (Paced Auditory Serial Addition Test), and on word and face recognition tasks.

Ponsford et al. (2000) conducted a similar study where they compared 84 mild TBI patients seen in the emergency department to 53 emergency department patients with "minor injuries" on the Symptom Checklist-90- Revised (SCL-90), the PASAT, the New Adult Reading Test (NART), the Rey Auditory Verbal Learning Test (RAVLT), the Digit Span and Digit Symbol (DSST) subtests of the WAIS-R, a reaction time test, the Speed of Comprehension test, and on the Survey of Recent Experiences. At one week post-injury, the mild TBI patients performed significantly lower on the DSST and Speed of Comprehension tests, indicating slowing of information processing. Subjectively, they reported headaches, dizziness, fatigue, visual disturbance and memory difficulties. These symptoms had largely resolved by three months, with no impairment evident in neuropsychological measures. However, a subgroup of 24% was highly distressed and continued to suffer from post concussive symptoms, particularly headaches and concentration difficulties. Factors associated with prolonged symptoms include a history of previous head injuries, neurological or psychiatric problems, students, females, and where their TBI was a motor vehicle accident.

In another study Mathias, et al. (2004) compared 40 mild TBI patients with 40 matched controls on a number of neuropsychological tests of selective and sustained attention, verbal and non-verbal fluency, and verbal memory, reaction time tasks, which requires both inter and intra hemispheric processing of visual and tactile information at one month post-injury. The mild TBI group demonstrated deficits in attention, non-verbal fluency, and verbal memory. In addition, they also demonstrated slower visual and tactile reaction times. They found that mild TBI patients demonstrated problems in the speed and accuracy with switching attention, the speed

with selecting relevant from irrelevant information, initial learning of verbal information, and their immediate and delayed recall of verbal information.

Landre, Poppe, Davis, Schmaus, and Hobbs (2006) examined the cognitive performance and symptom characteristics of hospitalised mild TBI patients and comparable trauma controls 4 to 5 days post-injury, and found that mild TBI subjects performed significantly worse than the controls.

Stulemeijer, Vos, Bleijenberg, and van der Werf (2007) compared a group of non-referred emergency department admitted mild TBI patients with and without cognitive complaints. They looked at demographic variables and injury characteristics, neuropsychological test performance, and self monitoring of perceived cognitive problems. A group of 79 patients completed the RPQ at six months post-injury; in addition they also monitored concentration problems and forgetfulness during 12 consecutive days. They found that 39% of patients self-reported cognitive complaints. These were strongly related to lower educational levels, emotional distress, personality, and poorer physical functioning especially fatigue, but not to injury characteristics.

Given these somewhat contrasting findings, several meta-analyses were conducted to look at neuropsychological functioning post mild TBI. Binder, Rohling, and Larrabee's (1997) study included participants assessed at least three months post-injury who had a history of mild TBI rather than just symptom complaint (i.e., population-based or unselected samples). They identified 11 studies and calculated effect sizes from eight different studies and found the overall effect to be quite small ($g=0.07$). When effect sizes were calculated for specific neuropsychological domains, attention was the only cognitive domain that had an effect size significantly greater than zero ($g=0.17$). Schretlen and Shapiro (2003) wanted a more

comprehensive review and conducted another meta-analysis. They included population-based or unselected samples of mild TBIs of all severities instead of just hospitalized samples. Based on 15 studies, the overall neuropsychological effect size (d) for mild TBI was 0.24. They also grouped studies of mild TBI into four time frames post-injury: 7 days, 7–29 days, 30–89 days, and greater than 89 days, and found significant differences across these time frames (d=0.41, 0.29, 0.08, and 0.04, respectively). However, the neuropsychological effect size was not significantly different from zero by 30–89 days post-injury. Although, these investigators did not report effect sizes by different neuropsychological domains, and some researchers believe it is possible that some domains may show residual impairments not captured by the overall effect size. Hence, Belanger et al. (2005) conducted another meta-analysis to determine the impact of mild TBI across nine cognitive domains. They included 39 studies involving 1,463 cases of mild TBI and 1,191 control cases. They found the overall effect of mild TBI on neuropsychological functioning was moderate (d=0.54). However, the findings were moderated by several factors: cognitive domain, time since injury, patient characteristics, and sampling methods. Acute effects, defined as less than 3 months post-injury were greatest for delayed memory and fluency (d=1.03 and 0.89, respectively). However, this acute effect was reduced to almost zero by three months post-injury, confirming Schretlen and Shapiro's (2003) findings. More specifically, in unselected or prospective samples, the overall analysis revealed no residual neuropsychological impairment by 3 months post-injury (d=0.04), which is consistent with the literature. In contrast, clinic-based samples and samples including participants in litigation were associated with greater cognitive deficits (d=0.74 and 0.78, respectively at 3 months or greater). In fact, they found litigation to be associated with stable or worsening of cognitive functioning over time.

In summary, a large body of research suggests a decline in cognitive functioning, and an increase in post concussive symptoms at various points post-injury, particularly during the first three months, although a small number of studies have found minimal or no evidence of such changes. As for those studies which show cognitive deficits, it appears that information processing speed and attention are the most affected cognitive domains and that there appears agreement in the literature that most cognitive deficits post mild TBI resolve in the first three months. Some researchers believe the inconsistency in findings is likely due to methodological variability between studies, particularly older studies, and indeed most studies which have found minimal or no differences are older studies, which used small, and potentially non representative samples with differing diagnostic criteria for mild TBI (Landre, et al., 2006).

Causes of cognitive deficits post mild TBI

A common mechanism underlying deficits post mild TBI are thought to be the result of DAI, the shearing and tearing of axons when the head is rapidly accelerated or decelerated. Extensive DAI can be produced even in mild TBI, leading to cognitive deficits (Heilman & Valenstein, 2003; Suh, Kolster, Sarkar, McCandliss, & Ghajar, 2006). Diffuse brain damage in the frontal and temporal lobes, corpus callosum, and fornices in those with mild TBI have been found through neuro-radiological and neuro-pathological investigations (Mathias, et al., 2004). Diffuse damage involving the fronto-temporal regions and white matter pathology involving the corpus callosum can result in subtle information processing deficits (Mathias, et al., 2004). Some believe that deficits in information processing capacity post mild TBI causes other cognitive difficulties, either in terms of processing speed, or in terms of the amount of information that can be handled concurrently (Bogdanova & Verfaellie, 2012).

Risk factors for cognitive impairments post mild TBI

A number of potential risk factors have been linked to post mild TBI cognitive impairments as mentioned in the above discussed studies, including the mechanism of injury, pre-morbid traits, and litigation. Potential risk factors will be discussed in more details in the following section.

Hanon, Demery, Martinovich, and Kelly's (1999) study of 100 mild TBI patients referred to an outpatient concussion clinic prospectively found that the mechanism of injury appears to have some value in predicting post-injury cognitive deficits and vocational outcomes. Namely, assault and being struck by a falling object resulted in a significantly greater level of cognitive deficits and worse vocational outcome than other mechanisms. Those who were assaulted also revealed comparatively worse cognitive outcomes, and 90% of those who were assaulted had modified or poor vocational outcome.

Repeated mild TBIs have been shown to reduce cognitive performance even beyond three months post-injury, indicating it may be a risk factor. Wall et al. (2006) attempted to determine the effects of a single and repeated "concussions" by assessing 698 jockeys in the United Kingdom for neurological and neuropsychological symptoms of concussion at least three months post-injury. They found that those with multiple historical concussions showed decrements on measures of response inhibition and divided attention when compared to those with a single concussion. These results have been replicated with studies with rats, where deficits in the hippocampal region were found (Aungst, Kabadi, Thompson, Stoica, & Faden, 2014; Slemmer, Matser, De Zeeuw, & Weber, 2002). Stulemeijer, et al. (2007) on the other hand found that those who reported cognitive complaints were strongly related to pre-morbid traits: lower educational levels, emotional distress, personality, and poorer physical functioning (e.g., fatigue), but not to

injury characteristics. Some have found litigation to be associated with poorer cognitive outcomes. For example Belanger, et al. (2005) found that cognitive performances of their clinic-based participants was associated with being involved in litigation, their cognitive functioning worsened over the first three months post-injury.

In conclusion, various potential risk factors for negative outcomes after mild TBI have been identified; however, there is no one set of established risk factors to date.

Emotional and behavioural outcomes

Overtime, the symptoms of mild TBI tend to shift from somatic to psychological (Anderson, et al., 2006; Hall, et al., 2005). Common psychological disorders post mild TBI include depression and anxiety (Bryant et al., 2010). High rates of depression have been reported such as those reported in (Draper & Ponsford, 2009; Rapoport, McCauley, Levin, & Song, 2002), who found 100% of their mild TBI participants scoring in the clinically significant range. While only 42% and 28% in the severe and very severe injury groups respectively scored in the same range, supporting the claim that unlike cognitive impairments, emotional problems are not related to injury severity (Levin, et al., 1987; Rapoport, et al., 2002). Patients suffering from both depression and anxiety is common, (Rapoport, et al., 2002)found more than one-third of patients with mild TBI showed evidence of anxiety and depression. They may also display a lack of emotions, emotional lability, mood swings, or apathy (Arciniegas, Anderson, Topkoff, & McAllister, 2005; Bryant, et al., 2010). Behavioural changes are also common post mild TBI, these commonly include irritability, restlessness, aggression, impulsiveness, fatigue, loss of social judgment, inability to tolerate stress or alcohol, and a lack of motivation (Hall, et al.,

2005). The following section will discuss emotional and behavioural changes by examining various studies looking at these issues post mild TBI.

Deb, Lyons, Koutzoukis, Ali, and McCarthy (1999) estimates about 18% of those with mild TBI develop a psychiatric illness within the first year of their injury, with depression being the most common psychological sequel of a mild TBI. Jorge, Robinson, and Starkstein (1993) followed 66 mild TBI patients during the first year post-injury, and found that 25.8% of the sample were diagnosed with depression three months post injury. In another study, Goldstein, Levin, Goldman, Clark, and Altonen (2001) compared 35 patients mild or moderate TBI aged 50 years and over who were prospectively recruited from acute care hospitals with a group of matched controls. Participants were assessed up to two months post-injury. The authors found that both mild and moderate patients exhibited significantly greater levels of depression and anxiety than the control group.

Levin et al. (2001) compared depression and stress between TBI patients and patients with trauma. The majority of the TBI group consisted of mild TBI patients (n=60, 85%) and a few moderate TBI patients (n=9). They assessed participants at three and six months post-injury using the Structured Clinical Interview for DSM-IV, the Center for Epidemiologic Studies Depression Scale, the Posttraumatic Stress Disorder Checklist, the Extended Glasgow Outcome Scale, the Community Integration Questionnaire, the 6-trial Verbal Selective Reminding Test, the Rey-Osterrieth Complex Figure, the Symbol Digit Modalities Test, the PASAT, the Grooved Pegboard, the Wisconsin Card Sorting Test, and the Social Support Questionnaire. They found that 18% of the sample reported depression, 13% met criteria for PTSD, and 58% encountered moderate disability at six months post-injury.

Lange et al. (2012) compared 83 military personnel with mild to moderate TBI. They further divided participants into three injury severity groups: 24 uncomplicated mild TBI, 17 complicated mild TBI, and 42 moderate TBI. They were assessed on the Personality Assessment Inventory within six months post-injury, with 73% of participants evaluated within three months post-injury. They found that the uncomplicated mild TBI group had significantly higher scores on anxiety related disorders and aggression scales compared to the complicated mild TBI group, but not the moderate group. They concluded that a substantial minority (just over 15%) had highly elevated scores particularly on the Somatic Complaints, Depression, Schizophrenia, Borderline Features, Antisocial Features and Stress clinical scales. While 20.8% of the uncomplicated mild TBI group and 11.5% of the complicated mild group met criteria for "significant psychological distress" on the depression, anxiety, anxiety-related disorders, or aggression scales. The authors considered these to be small, given that most of these participants were medically evacuated from Iraq or Afghanistan anywhere from two to 26 weeks prior to being evaluated, that 75% or more were not endorsing high levels of psychological distress on the Personality Assessment Inventory as expected by the authors.

In a recent study by Waljas et al (2014) 48 prospectively uncomplicated mild TBI patients recruited from an emergency department in Finland were compared with 24 healthy controls. A brief battery of self-report questionnaire was administered, including measures of post concussion symptoms, depression, and fatigue approximately three weeks post-injury. The mild TBI group reported a greater number of post concussion symptoms and fatigue, but not depression.

However, depression after mild TBI has been found to be associated with self reported increases in the number and perceived severity of other PCS symptoms, including headache,

dizziness and blurred vision (Fann, Katon, Uomoto, & Esselman, 2005). Depression has also been found to increase feelings of anger, aggression, suicide risk, and cognitive dysfunction (Fann, et al., 2005). Those who develop emotional and behavioural difficulties post mild TBI tend to be older, have lower levels of education, marital discord, poor interpersonal relationships, financial instability, a history of psychiatric disorders, pre-morbid personality disorders, and alcoholism (Chaudhury, et al., 2013; Deb, et al., 1999).

In summary, it appears that most studies have found psychological deficits post mild TBI, with depression being the most common complaint.

Activity and participation in mild TBI survivors

This domain focuses on one's ability to maintain one's role in society and to maintain one's relationships with others (Petchprapai & Winkelman, 2007). It involves one's interaction with others to fulfil his or her affection needs. Outcome measures focus on the giving and receiving of love, respect, and value. Stålnacke (2007) investigated the relationship between psychosocial functioning through assessing community integration and social support with post concussion symptoms in a population based cohort of 163 mild TBI patients. They found that the total CIQ score to be negatively correlated with the RPQ, suggesting the presence of PCS is linked to lower community integration, as well as higher levels of depression as measured by the Beck Depression Inventory in their study up to three years post-injury. In addition, they found male participants to have lower number of potential supportive persons than females. In another study of mild TBI patients and match healthy controls, mild TBI patients of both genders reported lower total number of supportive persons and lower satisfaction with support (Tomberg,

Toomela, Pulver, & Tikk, 2005). The authors suggested that this was a sign of malfunctioning supportive network which did not correspond to the patient's needs (Tomberg, et al., 2005).

The other aspect of this domain is vocational outcomes, where vocation refers to one's ability to work, both paid and unpaid; or participate in work to promote full integration and participation in society (Parker, Szymanski, & Patterson, 2005). In addition, it includes education and training. For some with mild TBI, returning to work or school is one of the most difficult experiences. A number of factors may hinder this transition, such as memory issues, fatigue, and psychological state. Petchprapai and Winkelman's (2007) literature review describes seven studies (Cicerone & Azulay, 2002; Englander, Hall, Stimpson, & Chaffin, 1992a; Kay, Newman, Cavallo, Ezrachi, & Resnick, 1992; McCullagh & Feinstein, 2003; M. J. Rapoport, S. McCullagh, D. Streiner, & A. Feinstein, 2003; Ruffolo, Friedland, Dawson, Colantonio, & Lindsay, 1999; Stranjalis et al., 2004) which assessed social and economic outcomes following mild TBI. They concluded that results are inconsistent based on these studies, where three studies (e.g., Englander, et al., 1992a; Kay, et al., 1992; Stranjalis, et al., 2004) reported between 84% to 88% returned to work between one week and three months post injury, while Ruffolo, et al. (1999) found only 42% returned to work at three months, and that 30% of those who returned to work required modifications to their jobs. In another study, the rate of return to work at six months post-injury was related to the severity of the brain injury, where they found 38% of those with GCS scores of 13-14 returned to work compared to 60% of those with a GCS of 15 (McCullagh & Feinstein, 2003). Boake et al. (2005) looked at a sample of 210 mild to moderate TBI patients, and found that 56% began work within six months post-injury, and 61% were working at their six month follow-up assessment.

Conclusion

Despite the inconclusive and sometimes inconsistent findings, many would agree that not all mild TBI patients make full recoveries, particularly within the first three months. There are a number of factors which may explain this inconsistency. First of all, as can be seen in various studies and meta-analyses discussed above, different mild TBI inclusion criteria/exclusion criteria were used; this is common in clinical theoretical, and empirical literature where definitions of mild TBI vary extensively(Petchprapai & Winkelman, 2007) . Secondly, different outcome measures were employed to define and measure outcomes. Thirdly, participants were measured at different time frames. As concluded by Pertab, James, and Bigler, (2009), these methodological heterogeneity in studies significantly limits conclusions that can be drawn.

Purpose of this study

As discussed in the previous chapter, although many hospital based studies have been conducted, the true incidence of mild TBI is unknown, and there is agreement in the literature that the true incidence is likely to be grossly underestimated. Mechtler, Shastri, and Crutchfield (2014) believes that this "silent epidemic" is underreported, often remains undiagnosed, and the consequences are under-recognised. Given the potentially debilitating outcomes for some mild TBI survivors, the true incidence of mild TBI would allow appropriate planning of rehabilitative treatments to reduce the burden on the individual, families, and society. Fortunately, the majority of patients recover fully from mild TBI without obvious residual symptoms; however a proportion of patients continue to experience persistent symptoms months or even years post mild TBI. It is estimated that between 10%-50% of patients with mild TBI continue to experience symptoms six to 12 months post-injury (Bazarian & Atabaki, 2001; Hall, et al., 2005;

Iverson, 2005); and these can be very disabling for the patients and their families. A number of factors have been linked to increased risk of experiencing persistent PCS symptoms after mild TBI. These include demographic variables such as older age, female gender, low SES, history of psychiatric disorder, history of substance abuse, or presence of alcohol at time of injury (Gasquoine, 1997; Hall, et al., 2005). The severity of the injury has also been compared to functional impairment resulting from mild TBI. However, outcomes of the individual do not necessarily correspond to the initial severity of injury (New Zealand Guideline Group, 2006). In fact, there is some evidence to suggest that people with mild TBI and an initial GCS score of 13 have worse outcomes than those with a score of 14 to 15 (Hsiang, et al., 1997). Some authors are advocating for further categories within mild TBI to better reflect likelihood of poor outcomes (Hsiang, et al., 1997). For example, Servadei et al. (2001) proposed that mild TBI be further classified as low risk mild head injury, medium risk mild head injury and high risk mild head injury, where low risk refers to those with a GCS of 15 and without a history of loss of consciousness, amnesia, vomiting, or diffuse headache; medium risk to those with a GCS of 15 and one or more of the following symptoms: loss of consciousness, amnesia, vomiting, or diffuse headache; and high risk to those with a GCS of 14 or 15, with a skull fracture and/or neurological deficits.

The present study is a population based study with the following specific aims:

1. To determine the incidence of mild TBI over a one year period in Hamilton and Waikato districts; including age, sex, ethnicity-specific incidence, and residency, mechanism of injury;
2. To describe the outcomes (psychological, psychosocial and cognitive) of patients with mild TBI at 1 and 6 months post injury;

3. To identify the factors associated with positive and negative outcomes (defined as presence vs. absence of PCS in accordance with DSM-IV diagnostic criteria) at 6 months post-injury; such as demographics, socioeconomic status, type and severity of injury; and
4. To examine the accuracy of Servadei, et al.'s (2001) high vs. low risk mild TBI categories in predicting who will develop PCS in accordance with DSM-IV diagnostic criteria at 6-months post-injury.

The two primary hypotheses of this study were: higher incidences of mild TBI, particularly for indigenous people (Māori) given previous findings from hospital based studies as discussed in Chapter I. Secondly, it is predicted that those in higher risk groups as classified by Servadei, et al.'s (2001) sub-classification system would be more likely to develop PCS.

CHAPTER III: METHODS

Context of Study

This was a prospective study of incidence, and short term (1 and 6 month) neuropsychological and functional outcomes of adults with mild TBI. This study sourced mild TBI participants from a larger population based TBI incidence and outcomes study Brain Injury Outcomes New Zealand in the Community (BIONIC). It is of note that the methodology described is specific to the BIONIC study, where some amendments were made to this wider study to accommodate the specific aims of this study. This will be discussed in more details under the section of Procedures on page 68. The BIONIC study used a prospective and retrospective population based register to ascertain all cases of TBI (all ages, all severities) that occurred in the "usually resident" population of Hamilton (Urban) and Waikato (Rural) districts (a general population representative of NZ) during a 12-month period from March 1, 2010 to February 28, 2011. This area of NZ is depicted in Figure 3 below.

Figure 3. Map of New Zealand, with the Hamilton and Waikato districts highlighted

Participants

For the purposes of identifying incidence of adult mild TBI, the sample included all 784 cases who met our inclusion/exclusion criteria. Participants included all residents of the Hamilton and Waikato region aged 16 years or older, who had a new brain injury between 1st March 2010 and 28th February 2011. The clinical identification of TBI included presence of one or more of the following:

- Confusion or disorientation
- Loss of consciousness
- Post-traumatic amnesia
- Other neurological abnormalities, such as focal neurological signs, seizure and/or intracranial lesion

Exclusion criteria were that these manifestations of TBI were not due to drugs, alcohol or medications, caused by other injuries or treatment for other injuries (e.g., systemic injuries, facial injuries or intubation), or caused by other problems (e.g., psychological trauma, language barrier or co-existing medical conditions). Mild TBI was defined as "an acute brain injury resulting from mechanical energy to the head from external physical forces" (see page 8, Chapter I), with sub classifications defined as per Servadei, et al. (2001) (see page 11, Chapter 1).

For the purposes of describing one and six months' outcomes of adult mild TBI, the sample included all those participants from the above sample who, in addition, met the inclusion criteria: (1) provided written informed consent to participate in follow-up assessments; and (2) participated in the one and/or six month assessments.

Figure 4 presents a summary of the recruitment of the mild TBI sample, where participants included all adults who experienced a mild TBI during the 12 month period of case ascertainment. As seen in Figure 4 from the 784 incident mild TBI patients identified, 406 initially agreed to be contacted, 355 declined participation, 396 completed the baseline assessment, 362 completed the one month follow assessment, and 297 completed the six month follow up assessment.

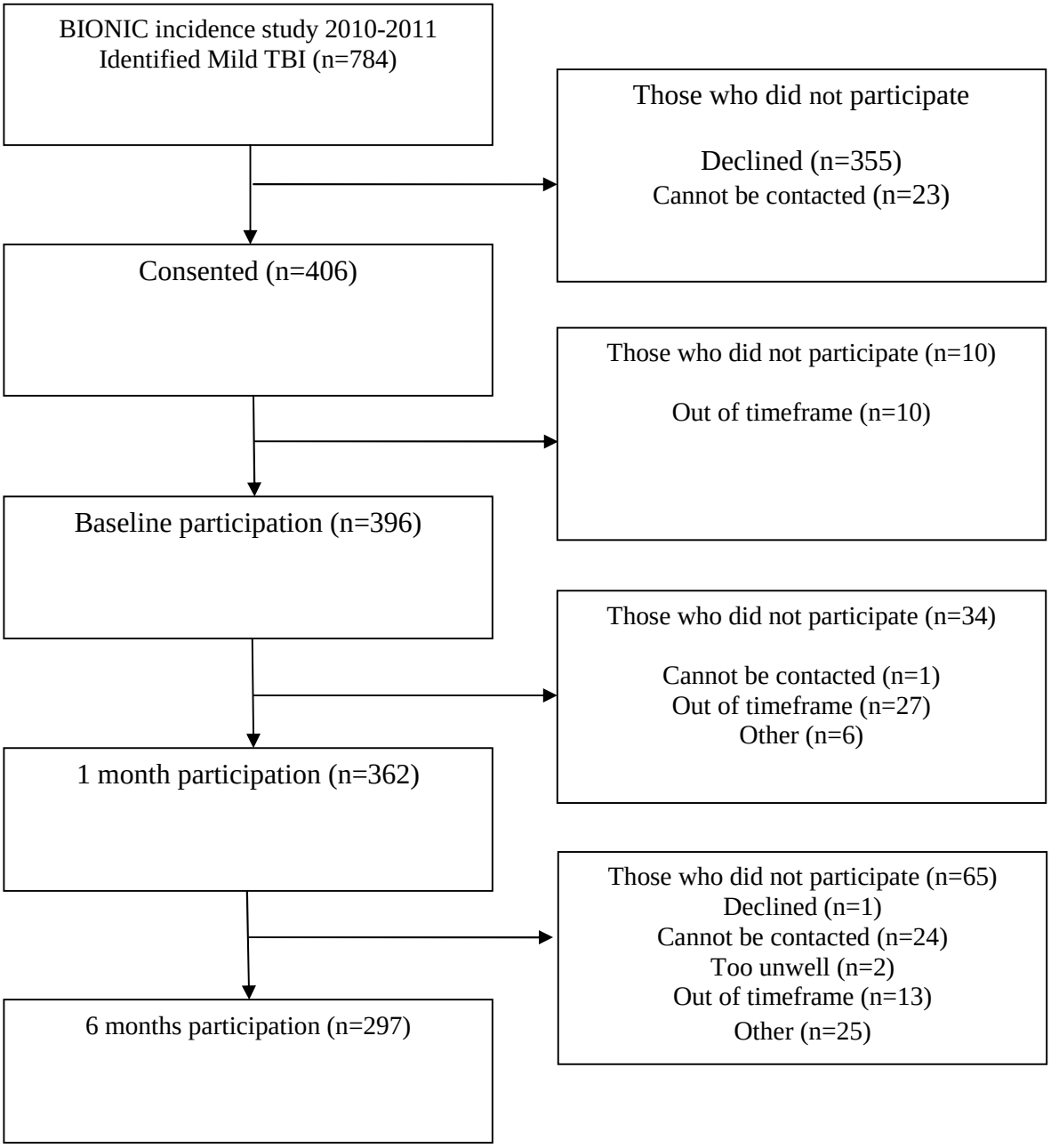

Figure 4. Summary of sample recruitment.

Missing: those who consented to participation, but were unable to be contacted. Out of timeframe: consented to participate, however assessment was not completed within specified timeframe. Too unwell: consented to participate, however did not complete assessment due to sickness.

Table 4 below presents the demographic and injury characteristics of all 784 participants who met criteria (defined as having had a mild TBI "an acute brain injury resulting from mechanical energy to the head from external physical forces") for inclusion in the incidence

aspect of this study. Where data is available, these are also presented for each of the mild TBI sub classifications (low risk mild head injury, medium risk head injury, and high risk head injury) as per Servadei, et al.'s (2001) criteria (refer to Table 2 for details); as well as for those who declined to participate. It is of note that there are missing data for the excluded group who did not participate in the assessments. The demographics for the total mild TBI cases are relevant to our first aim which was the examination of the incidence of mild TBI by demographic factors (e.g., age, gender, etc). Participants were aged between 16 to 99 years with the mean age of 37 years. Most (66.20%) of the mild TBI patients self-identified as New Zealand Europeans (NZE), while 29.72% self-identified as Māori, 35 (4.46%) self-identified as Pacific Islanders, 2.04% self-identified as Asian, and 11.48% self-identified as other ethnicity, note that participants were able to identify themselves in more than one ethnicities, therefore the percentages do not add up to 100. Almost half of the participants were working full time prior to their injury. Nearly half identified high school as their highest education level.

Table 4

Demographic and injury characteristics for participants by TBI severity (N = 784), and for those not consenting and not included in these analyses (N = 355).

	Low risk Mild TBI group		Medium risk Mild TBI group		High risk Mild TBI group		All Mild TBI (N = 784)		Excluded Participants (N = 355)		Significance of Difference between included and excluded
Variable	N	%	N	%	N	%	N	%	N	%	
Age Mean (years)	35		33		40		37		38		t(1,759)=0.570, p = .451
Gender											
Female (%)	66	37.5	64	37.6	170	38.8	300	38.3	124	34.9	
Male (%)	110	62.5	106	62.4	268	61.2	484	31.7	231	65.1	
Ethnicity											Chi^2=31.897(3), p < .001
European (%)	113	58.2	121	61.1	285	56.9	519	58.1	191	53.8	
Māori (%)	53	27.3	42	21.2	138	27.5	233	26.1	98	27.6	
Pacific Island (%)	8	4.1	11	5.6	16	3.2	35	3.9	11	3.1	
Asian (%)	4	2.1	5	2.5	7	1.4	16	1.8	16	4.5	
Other (%)	16	8.2	19	9.6	55	11.0	90	10.1	13	3.7	
Marital Status											$Chi^{2(2)}$=1.374, p = .712
Married/Civil union/De facto	25	48.1	26	32.9	117	45.9	168	43.5			
Separated/Divorced/Widowed	4	7.7	10	12.7	40	15.7	54	14.0			
Never married (single)	23	44.2	42	53.2	98	38.4	163	42.2	1	0.3	
Unknown	0	0.0	1	1.3	0	0.0	1	0.3	354	99.7	
English as first language											$Chi^{2(2)}$= 670.216p < .001

Missing	124	70.5	91	53.5	183	41.8	398	50.8			
N	2	1.1	4	2.4	7	1.6	13	1.7			
Y	50	28.4	75	44.1	248	56.6	373	47.6	1	0.3	
Highest education obtained											$Chi^{2(3)}$= 1.143, p =.767
Primary School	1	1.9	2	2.5	13	5.1	16	4.2			
High School	25	48.1	34	43.0	121	47.6	180	46.8	1	0.3	
Polytechnic	11	21.2	25	31.6	68	26.8	104	27.0			
University	15	28.8	18	22.8	52	20.5	85	22.1			
Work situation pre injury											$Chi^{2(7)}$=5.717, p = .573
Full time paid work	28	53.8	40	51.9	109	42.7	177	46.1			
Part time paid work	5	9.6	8	10.4	33	12.9	46	12.0			
Retired	0	0.0	0	0.0	23	9.0	23	6.0			
Unemployed or redundant	3	5.8	2	2.6	13	5.1	18	4.7			
Beneficiary	6	11.5	10	13.0	20	7.8	36	9.4			
Homemaker	2	3.8	3	3.9	11	4.3	16	4.2			
Student	7	13.5	12	15.6	39	15.3	58	15.1	1	0.3	
Other	1	1.9	2	2.6	7	2.7	10	2.6			

In terms of case ascertainment, as can be seen in Table 5 below, more than 75% of participants were located in hospitals, with the remaining 25% identified through GPs, accidents and medical clinics, self referrals, the ACC database and other sources.

Table 5

Table showing frequency and percentages of case ascertainment for participants

How case was located	Frequency (n)	Percentage (%)
Hospital	600	76.5
General Practitioner	67	8.5
Accident and Medical Clinics	83	10.6
Self referrals	12	1.5
ACC database	3	0.4
Other	19	2.4

ACC: Accident Compensation Corporation

In terms of mechanism of injury, falls was the most common cause followed by assault, MVA, recreational and industrial as shown in Table 6. As for the worst GCS recorded, more

than 75% of participants reported a score of 15. As for LOC, more than 75% less than a minute. In terms of PTA, again, 75% reported less 24 hours of PTA, with the remaining participants reporting a PTA of up to one day.

Table 6

Injury characteristics for participants by TBI severity

	Low risk Mild TBI group		Medium risk Mild TBI group		High risk Mild TBI group		All Mild TBI	
Variable	N	%	N	%	N	%	N	%
Mechanism of injury								
MVA	33	19.0	29	17.1	69	15.8	131	16.8
Fall	40	23.0	49	28.8	169	38.8	258	33.1
Industrial	6	3.4	3	1.8	7	1.6	16	2.1
Recreational	31	17.8	32	18.8	27	6.2	90	11.5
Assault	33	19.0	30	17.6	120	27.5	183	23.5
Other	31	17.8	27	15.9	44	10.1	102	13.1
GCS								
14	1	2.7	3	9.1	48	29.4	52	22.3
15	36	97.3	30	90.9	115	70.6	181	77.7
LOC (minutes)								
Missing	5	3.7	16	10.5	35	9.2	56	8.4
0	117	87.3	61	39.9	177	46.6	355	53.2
1	10	7.5	48	31.4	94	24.7	152	22.8
2	2	1.5	8	5.2	23	6.1	33	4.9
3	0	0.0	2	1.3	10	2.6	12	1.8
4	0	0.0	3	2.0	3	0.8	6	0.9
5	0	0.0	8	5.2	16	4.2	24	3.6
10	0	0.0	1	0.7	12	3.2	13	1.9
15	0	0.0	1	0.7	6	1.6	7	1.0
20	0	0.0	2	1.3	1	0.3	3	0.4
30	0	0.0	3	2.0	2	0.5	5	0.7
PTA (hours)								
<24	6	100	1	50.0	2	50.0	9	75
24	0	0	1	50.0	2	50.0	3	25.0

MVA: motor vehicle accident; GCS: Glasgow Coma Scale; LOC: loss of consciousness; PTA: post-traumatic amnesia

Measures

Participants were asked to participate in assessments at baseline (within two weeks of injury), and then at one, six month and 12 month follow-ups. For the purposes of looking at

short term outcomes, only data for baseline, one and six month assessments were included in this study. Copies of the participant information sheet and participant consent form are in Appendix A, all assessments are included in the Appendices. In addition to questionnaires relevant to this study, which will be discussed in more detail under the section on Procedures on page 68? , assessment forms also include additional questionnaires used by the BIONIC study.

Baseline only measures

Baseline assessments included information on participant's age, gender, ethnicity, date and time of injury, date of first presentation of injury, brain injury characteristics, co-morbidities (e.g., associated injuries, diagnostic tests); and injury severity. A copy of this can be found in Appendix C.

Baseline and follow-up outcome measures (Appendices D to L)

The following information was collected at baseline, 1 and 6 months: Demographics, mood, social support, day-to-day cognition, post-concussive symptoms, cognitive Abilities, health related quality of Life (HRQoL), and community integration. In addition, a number of different measures were administered as part of the BIONIC study, but these additional data have been excluded from this study. Table 7 shows the timings of the data collected at various time periods. The section below describes each of the measures relevant to this study. The section below first reviews measures of impairment, disability, handicap, HRQoL and mood followed by information on measures of cognitive function.

Table 7

Injury characteristics for participants by TBI severity

Demographics and Injury Characteristics - Baseline Assessment only	
Demographic	Age, gender, ethnicity, date and time of injury, date of first presentation of injury, brain injury characteristics, co-morbidities (e.g. associated injuries, diagnostic tests)
Injury Severity	Glasgow Coma Scale Westmead PTA scale

Assessments conducted at Baseline, 1 and 6 month follow-up	
Demographics	Employment status, living arrangements, educational level, history of medication, alcohol/drug and substance use, preadmission functional ability, marital status, height and weight, injury mechanism, co-morbidities, medication use
Global Outcome	Glasgow Outcome Score
Employment & education	Return to or changes in employment; Educational status
Mood	Hospital Anxiety and Depression Scale
Social Support	Duke-UNC Functional Social Support Questionnaire
Day-to-day cognition	Cognitive Failures Questionnaire
Post Concussive Symptoms	The Rivermead Post Concussion Symptoms Questionnaire
Cognitive Abilities	CNS Vital Signs Test
Health related quality of Life	RAND 36-Item Health Survey
Community Integration	Community Integration Questionnaire

Impairment, Disability, Handicap and Health related quality of life measures

Glasgow Coma Scale (GCS; Teasdale & Jennett, 1974). The GCS is a neurological scale used to assess the conscious state of a person following injury. The GCS score ranges from 3 to 15 where 3 indicates a deep coma or death and 15 indicates a fully conscious state. The scale comprises three test categories for eye, verbal and motor responses. The scores for these categories range from 1 (does not open eyes) to 4 (opens eyes spontaneously) for eye opening response; 1 (makes no sounds) to 5 (oriented, converses normally) for verbal response; 1 (makes no movements) to 6 (obeys commands) for motor response. The GCS total score comprises the sum of scores in the three categories.

The GCS has been used widely in TBI studies and has high criterion validity as it is a valid measure for assessing post TBI level of consciousness and predicts functional outcomes (Prasad, 1996). The GCS is also a reliable scale, having high inter-rater reliability (i.e., 96.4% agreement) among experienced users (Lindsay, Teasdale, & Knill-Jones, 1983; Prasad, 1996; Rowley & Fielding, 1991). In this study, the accepted criteria for mild TBI on the GCS at time of injury (that is a score of 14 or over), was used (Servadei, et al., 2001).

Westmead PTA scale (WPTA; Ponsford, et al., 2004; Shores, Marosszeky, Sandanam, & Batchelor, 1986). The WPTA is a 12-item scale which assesses orientation, memory for a face and name given to a photograph and three pictures of objects. It consists of seven orientation questions (e.g., What month are we in?) and five memory items. For example, the patient is shown a photo on first administration, and then asked to remember the face and in subsequent administrations, they are asked to identify the face from an array of these three possibilities. It takes approximately three minutes for most people, but may take up to 15 minutes for non-verbal patients. A person is said to be out of PTA on the first of three consecutive days of a perfect

score (12/12). It is useful for assessment of post-traumatic amnesia and monitoring recovery after TBI. This score was obtained from medical notes if it was administered.

RAND 36-Item Health Survey (SF-36; Ware, Kosinski, & Keller, 1994). The SF-36 is a multipurpose, standardised instrument that was intended to measure overall health in population studies. It assesses health related quality of life using 36 multiple choice items that can be administered in 5 to 10 minutes. The survey is suitable for individuals aged ≥14 years and can be self-administered or completed by interview (Anderson, Laubscher, & Burns, 1996; Anderson, et al., 2006). The scale assesses eight areas of quality of life: 1) physical functioning (PF); 2) role limitations due to physical health problems (RP); 3) role limitations due to emotional problems (RE); 4) vitality, energy and fatigue (VT); 5) general mental health (MH); 6) social functioning (SF); 7) bodily pain (BP); and 8) general health perceptions (GH). The number of items in each scale varies. Most items are related to participants' functioning in the past one month, and there are a variety of response formats ranging from yes/no response, through three, four, five and six category responses. An example of a six category response to the item "In past 4 weeks how much of the time did you feel full of energy," to which the participant has choices ranging from 1- None of the time, to 6-All the time.

Scoring involves a two-step process. Items are assigned scores ranging from 0-100, where higher scores indicate better functioning and fewer problems. These are then added and a mean score is calculated for each of the 8 scales. Five of the scales (Physical Functioning, Role limitations due to Physical problems, Role limitations due to Emotional problems , Social Functioning, and Bodily Pain) are "unipolar", meaning that they measure health status as the absence of disability (e.g., a score of 100 on pain scale=no pain limitations). The other three (General Health Perceptions, Vitality (energy/fatigue), and Mental/Emotional Health

Perceptions) are "bipolar" scales, meaning they measure both positive and negative states of health (i.e., a score of ≥50 indicates a positive state of health [not just absence of illness]). The SF-36 also yields two summary scores; the Mental Component Summary (MSC) score, which is based on average scores from social functioning, vitality, role emotional and mental health, and the Physical Component Summary (PCS) score, which is based on scores of physical functioning, bodily pain, role physical and general health. Both component scores have a mean of 50 and a standard deviation of 10.

The SF-36 has proven to be reliable across many populations (Ware & Sherbourne, 1992). The SF-36's internal consistency and test-retest reliability are high for each of the 8 subscales (i.e., ≥ 0.80) apart from social functioning which had the median reliability of 0.76 (Ware, Snow, Kosinski, & Gandek, 1993). Reliability estimates for the summary scores (i.e., MCS and PCS) was found to be 0.90 (Ware, et al., 1994). It has been validated in persons with TBI (Findler, Cantor, Haddad, Gordon, & Ashman, 2001). Studies on content validity indicate that it includes 8 of the most frequently measured health concepts (Ware et al., 1993). The SF-36 is a widely used measure in TBI research (Emanuelson, Holmkvist, Bjorklund, & Stalhammer, 2003) and has been validated in NZ (Scott, Sarfati, Tobias, & Haslett, 2000; Scott, Tobias, Sarfati, & Haslett, 1999).

Glasgow Outcome Score (GOS; Jennett & Bond, 1975). The GOS is a well-validated measure of global functioning of independent living and social reintegration that is widely used in brain injury research (Pettigrew, Wilson, & Teasdale, 2003). This scale is the most widely used outcome measure following TBI (Wilson, Pettigrew, & Teasdale, 1998). This scale was developed to allocate patients into broad outcome categories and therefore reflects disability and handicap rather than impairment (Jennett & Bond, 1975). The GOS is a simple hierarchical

scale in which the patient's overall rating is based on the lowest of five outcome categories indicated: 1 (good recover), 2 (moderate disability - disabled but independent), 3 (severe disability - conscious but dependent); 4 (persistent vegetative state); and 5 (death). It can be reliably administered in-person or over the telephone (test-retest reliability 0.92 and inter-rater reliability 0.85) (Pettigrew, et al., 2003).

Social functioning and community integration

Two questionnaires were used to assess social functioning and community integration, the Duke-UNC Functional Social Support Questionnaire and the Community Integration Questionnaire.

Duke-UNC Functional Social Support Questionnaire (FSSQ; Broadhead, Gehlbach, de Gruy, & Kaplan, 1988). The FSSQ measures perceived amount and type of social support. The original questionnaire contained 14 items; however this was reduced to eight items after reliability testing. Three items were deleted because of lack of test-retest reliability (Broadhead, et al., 1988). Each item is rated on a 5-point scale ranging from 1 (much less than I would like) to 5 (as much as I would like). There are four domains of social support assessed: quantity of support, confidant support (having persons to talk to), affective support (manifestations of love, affection and empathy) and instrumental support (help when participant is sick in bed). All of the scores which load onto a total score from all 10 items are summed and then divided by 10 to obtain an average total score, with higher average scores indicating higher perceived support. The FSSQ has been found to have high test-retest reliability and adequate internal consistency (Broadhead, Gehlbach, de Gruy, & Kaplan, 1989).

Community Integration Questionnaire (CIQ; Willer, Rosenthal, Kreutzer, Gordon, & Rempel, 1993). The CIQ was developed to provide a measure of community integration after TBI. The CIQ consists of 15-items exploring the frequency the person engages in daily living activities across three subscales; home integration, social integration and productive activities. Subscales and a total community integration score are calculated by scoring the frequency of performing activities and whether these activities are completed alone or done jointly with others, and the nature of these other persons (e.g., with or without TBI). Three subscale scores are derived from each of the three subscales, and a total score CIQ is generated ranging from 0 to 29. Lower scores represent less integration into one's community and home environment or poor/negative outcome. Higher scores represent more integration. The Home Integration Scale (score range of 0-10) which includes questions that address completion of household responsibilities (e.g., "Who usually prepares meals in your household?"). Participants are asked to indicate their involvement in the task from 0=someone else, 1=yourself and someone else, 2=yourself alone. The Social Integration Scale (score range of 0-12) consists of questions that address level of engagement in financial responsibilities and social activities (e.g., "When you participate in leisure activities, do you usually do this alone or with others?"). For each question, the participant chooses the answer that best represents his/her participation level from 0=mostly never, 1=mostly with friends who have head injuries, 1=mostly with family members, 2=mostly with friends who do not have head injuries, 2=with a combination of family and friends. The Productivity Scale (score range of 0-7) comprised of questions that assess employment status and involvement in scholastic endeavours, vocational programs and voluntary work or other productive activities outside the home (e.g., "Please choose the answer below that best corresponds to your current work situation (during the past month). For this question, the

participants choose one of the following answers: Not working, but actively looking, Not working, not looking for work, Not applicable, retired due to age, part-time (< 20 hours per week), Full-time (> 20 hours per week).

The CIQ was originally validated on a small sample of participants with severe TBI (Willer, Linn, & Allen, 1993); and then developed with a larger sample of participants with primarily severe TBI and also with a matched controlled healthy sample (C Paniak, K Phillips, G Toller-Lobe, A Durand, & J Nagy, 1999). In the latter study, the researchers concluded that those who sustained a TBI generally had lower scores on the CIQ compared to normal controls. Sander et al. (1999) concluded that the factor structure has been found to be clinically and theoretically meaningful. The subscales and total scores show significant relationships with other widely used measures of outcome (C Paniak, et al., 1999).

Mood and emotion measures

Hospital Anxiety and Depression Scale (HADS; Zigmond & Snaith, 1983). The HADS is a well established and commonly used instrument for determining the levels of anxiety and depression an individual with illness is experiencing. Unlike other measures of depression and anxiety, it contains few somatic symptoms, which are common post TBI. It contains 14 items, seven questions measuring anxiety symptoms with the other seven measuring depression symptoms. Responses are based on relative frequency of symptoms over the past week, using a four point scale ranging from 0=Not at all to 3=Very often. Responses are summed to provide separate scores for anxiety and depression symptomatology with possible scores ranging from 0 to 21. Scores from 0 to 7 represents a normal level of anxiety or depression, 8 to 10 is considered mild, 11 to 14 is moderate, and 15 to 21 a severe level of anxiety or depression.

The HADS has high internal consistency with Cronbach alphas of 0.83 and 0.82 for the HADS subscales of anxiety and depression, respectively (Bjelland, Dahl, Haug, & Neckelmann, 2002) and it has been used with TBI groups (Anson & Ponsford, 2006; Hawley, 2003; J. Powell, Heslin, & Greenwood, 2002; Stilwell, Stilwell, Hawley, & Davies, 1998; Watanabe, Shiel, Asami, Taki, & Tabuchi, 2000). The HADS is also sensitive to changes in anxiety and depression during the course of disease and in response to psychotherapeutic and psychopharmacological intervention (Herrmann, 1997).

The Rivermead Post Concussion Symptoms Questionnaire (RPQ; King, Crawford, Wenden, Moss, & Wade, 1995). The RPQ was developed specifically for use with people after a TBI to assess the presence and severity of symptoms experienced that are common to PCS. It is the only measure of post concussion symptoms not designed for sports concussion, and the only measure for post concussion symptoms to date. The measure consists of 16 symptoms commonly found after a TBI and participants are asked to rate the severity with which they have experienced each symptom over the past 24 hours compared to how severe it was before the injury on a scale of 0='Not Experienced', 1='No More of a Problem', 2='Mild Problem', 3='Moderate Problem', 4='Severe'. The items include symptoms such as headaches, forgetfulness/poor memory, dizziness, and irritability. Scores are taken as sum of all symptom scores excluding scores of 1 as these indicate symptoms are unchanged since the injury. This gives a potential total score range of 0 (representing no change in symptoms since the TBI) to 64 (most severe symptoms).

Tests of cognitive function

CNS Vital Signs Test (CNS-VS; Gualtieri & Johnson, 2006). The CNS-VS is a computerised, brief self-administered clinical evaluation tool designed for screening purposes, and for serial administration with, for example, the content being randomly selected for each administration to reduce the effects of content. It is designed for evaluating cognition in neurological, psychiatric, and other clinical conditions. It was used here to evaluate and quantify the impact of mild TBI on neuropsychological functioning, and also as it is not used in clinical practice it was thought that this would then not cause any practice effects should participants be referred for neuropsychological assessment elsewhere. It comprises of five tests: verbal and visual memory, psychomotor speed, reaction time, complex attention and cognitive flexibility. Subtests include: Verbal Memory, Visual Memory, Finger Tapping, Symbol Digit Coding, Stroop Test, Shifting Attention Test, Continuous Performance Test, Perceptions of Emotions Test, Four Part Continuous Performance Test and Dual Task Test. The neurocognitive tests have been chosen carefully, they must meet eight different criteria, including: familiarity, reliability, practice effect, standardisation, validity, sensitivity, alternate forms, clarity and ease of administration.

The psychometric properties of the tests in the CNS-VS battery are very similar to those in the conventional neuropsychological tests upon which they are based (Gualtieri & Johnson, 2006). It is a reliable and valid measure; and sensitive to the most common causes of cognitive impairment, including mild TBI. With an average 62 day test-retest interval, reliability of the 25 scores generated by the CNS-VS, the majority have either good ($r > .8$) or moderate ($r > .7$) test-retest reliability, suggesting scores are relatively stable over time. It is of note also that the test-

retest reliability of psychomotor speed (r =.88) exceeds that for both conventional tests and other computerised test batteries (Gualtieri & Johnson, 2006).

Cognitive Failures Questionnaire (CFQ; Broadbent, Cooper, FitzGerald, & Parkes, 1982; Wallace, 2004). The CFQ is a 25-item questionnaire of memory and attention, and everyday errors in thinking from three categories: memory slips (e.g., absentmindedness), attention slips (e.g., fail to notice something relevant), and psychomotor slips (e.g., action slips). For example, "do you read something and find you haven't been thinking about it and must read it again?". Participants respond to items using a 5-point likert scale as follows: 0='never', 1='very rarely', 2='occasionally', 3='quite often', and 4='very often'. These are summed to produce a total score ranging from 0 to 100.

The CFQ has been found to be only weakly correlated with indices of social desirability or of neuroticism (Broadbent, et al., 1982). It is significantly correlated with ratings of the respondent by his or her spouse, and accordingly does have some external significance rather than reflecting only private opinion of the self. The score is reasonably stable over long periods, to about the same extent as traditional measures of trait rather than state measures (Broadbent, et al., 1982).

In summary, these measures have been carefully chosen after considering a number of factors including duration of administration, content, it's relevance for this study population and its statistical properties.

Procedures

This study obtained ethics approval as part of the BIONIC study which was granted ethical approval from the Multiregional Ethics Committee. The researcher requested the addition of

Servadei, et al.'s (2001) mild TBI sub-classification system to the original study in order to test for Aim 4 of this study.

This researcher was the only Auckland based research assistant within a team of research assistants in the BIONIC team led by a study manager.

Identifying TBI cases

To ensure complete case ascertainment, multiple overlapping sources of information from all new hospitalised and non-hospitalised mild TBI cases (fatal and non-fatal) was used. Research assistants conducted capture-recapture analysis which included: review of all private and public hospitals and emergency departments (e.g., surgery and neurosurgery departments), CT/MRI records, hospital discharge registers, coroner/autopsy records, death certificates, rest homes, community health services (GP practices, rehabilitation/outpatient clinics, sports clubs, physiotherapy clinics), Accident and Medical Centres in Hamilton and Waikato districts, St Johns ambulances, and the national funder of accident related health services (ACC) and NZ Health Information Systems (NZHIS) databases for all fatal/non-fatal TBIs within the study region. To capture mild TBIs occurring to those residents within the study region, but where the injury itself occurred outside of this region, hospitals from neighbouring regions (e.g., Auckland, Franklin, Coromandel Peninsula, Bay of Islands) were also reviewed.

More specifically, a surveillance system was set up across all medical services in Hamilton and Waikato districts. Mild TBI cases were identified by daily searches of presentations and admissions recording any diagnoses suggesting mild TBI or an accident at the Waikato hospital emergency department. This ensured that hospitalised patients who were already in hospital with another diagnosis but had also experienced a mild TBI were captured. All patients seen at the

hospital for an injury but who were not admitted were contacted by phone (by a researcher holding an honorary contract with the hospital) and asked the three study inclusion questions to determine if they experienced a mild TBI in their accident and whether they were eligible for the study (i.e., 3 study questions: Losing consciousness (knocked out); Being dazed, confused or 'seeing stars'; Not remembering the injury (what happened)).

Weekly checks were conducted of Waikato Hospital Trauma Unit, CT/MRI records, the medical surgery ward, neurological wards, GP clinics, St John Ambulance records and Waikato Concussion Clinic referrals. Monthly checks were also performed of the Waikato Hospital discharge register, private hospitals and rehabilitation providers, the local Prison and Auckland Public Hospital. Quarterly checks were carried out at Thames Hospital, sports centres, Intellectually Handicapped Children (IHC) and rest homes and community health services within the study region. This was done as people with acute TBI who are permanent residents care facilities (e.g., rest homes or hostels) are not necessarily transferred for care in hospital due to frailty.

To ensure identification of mild TBI cases not admitted to hospital, collaborations with all GPs and primary health organisations (PHOs) in the study region were developed. All GPs were given a detailed explanation of the study by a member of the study team. They were provided with information kits and other memory aids (e.g., coloured brochures, sticky labels, etc) to encourage identification of cases and refer to the study team . In addition, they were provided with $80.00 reimbursement for each newly identified case (e.g., any case that has not already been identified from another source). Cases referred from other health practitioners such as physiotherapists and nursing staff were also reimbursed with $80 for each new case. This payment was a form of "koha", which is common in Māori customs, and can be seen as a gift,

present, offering, donation or contribution. However, few referrers took up this offer as most cases were located by the study team, who maintained regular contact through visits, newsletters and meetings, to preserve awareness and focus on the study. All GPs were also given a referral pad to refer participants to the study quickly and easily.

Six monthly checks of the ACC database, WorkAOn (a specialist personal injury, claims and rehabilitation division of Aon Risk Services NZ Limited which manages personal accident and illness related claims for employers and life insurance companies, it is an independent claims administrator and rehabilitation co-ordinator in NZ), and Brain Injury New Zealand (BINZ) were also conducted. Annual checks were performed of coroner/autopsy records with any mention of TBI at the Hamilton and Waikato Coroner's office to identify people who may have died at the time of injury. Permission was obtained from the Registrar-General to access electronic notification from the central Wellington office of all relevant death certificates mentioning TBI issued over the study period.

The study was widely advertised using various methods to initiate and maintain awareness of the study in the community including: contact with regional community services such as Concussion Clinics and Hamilton Brain Injury Association, regular contact with the regional prison, and publicity via radio stations and local newspapers to encourage self referrals.

Final checks for completeness of case ascertainment were made by reviewing the New Zealand Health Information Services (NZHIS) database for all fatal and non-fatal TBI cases in the study population in 2010-2011 and hospital separations data for public and private hospitals, using ICD-10 codes for head injury (S.00-S.09): superficial injury of head; open wound of head; fracture of skull/facial bones; dislocation, sprain and strain of joints/ligaments of head; injury of the cranial nerves; injury of the eye/orbit; intracranial injury; crushing injury of head; traumatic

amputation of part of head; other/unspecified injuries of head), as either a primary or secondary diagnosis.

Each diagnosis of mild TBI was confirmed by review of the medical records (or clinical details) for each participant. Upon notification of a case, a Case Notification (Appendix B) was completed from the medical records for all identified mild TBI cases.

Contacting participants

A participant information sheet and consent form inviting potential participants to participate in the study was provided (either via mail or in person if the individual was in hospital) by the study manager after the participant was identified by a research assistant. If the participant was unable to provide consent, a proxy (i.e., someone who lives with or spends a substantial part of each day with the person) was identified and approached by a research assistant for consent to participate in the study on the TBI survivor's behalf.

Telephone interview and follow-up

Once a participant had indicated that they would like to participate in the study (i.e., by GP or self-referral or on being contacted by the study managers via a hospital search), the potential participant was contacted by a research assistant over the telephone. As an Auckland based research assistant, the researcher contacted all participants who were referred to Auckland for treatment, relocated to Auckland, or preferred to be seen in Auckland.

Initial Phone Contact

During the initial contact with participants, the researcher explained the study to the participant in full and participants were given the opportunity to ask questions. Verbal consent was obtained, and the first telephone assessment was conducted if it was a convenient time. Participants were also given the option of completing this during the face-to-face interview at a time and place convenient for them. Assessments were often conducted after hours and weekends; either at the participant's homes, workplace or school/university. The flexibility provided to participants aimed to reduce dropout rates by minimising disruptions to the participant's day, such as travelling time and cost involved. Those questions which could not be answered over the phone were completed during face-to-face interviews (i.e., GOS). The duration of telephone interviews were approximately 30 to 45 minutes.

Face to face interviews

The assessments were conducted within set timeframe. For example, the baseline assessment had to occur within two weeks of the injury and follow-up assessments within two weeks prior to or after the specific follow-up due date). After a brief review of the Participant Information Sheet, written consent was obtained when the researcher met the participant. Those who agreed to participate were assessed at their usual place of residence or other mutually convenient location. This assessment included an in-person administration of the questionnaires and neuropsychological test (i.e., CNS-VS). The duration of the face-to-face assessment was between 60 to 120 minutes (inclusive of additional questionnaires not part of this study). If a participant became fatigued during the assessment, they were given breaks or another time was arranged to complete the remainder of the assessment.

Once the data was collected and scored according to standardised procedures, it was entered into the study website. Upon completion of all 6-month assessments, those cases meeting inclusion criteria for these analyses (i.e., age ≥16 years of age, TBI classified as mild) were extracted into a SPSS 20.0 data file for analysis.

CHAPTER IV: RESULTS

Overview

The results of this study will be presented in four sections. The first section presents the age, gender and ethnicity specific incidence of mild TBI over a one year period in Hamilton city (urban) and Waikato (rural) districts; including incidence by ethnicity, injury severity, region and causes of injury. The second section describes the outcome (psychological, behavioural and cognitive) of participants at baseline, one and six months post-injury; including examination of within-subject change over time. Section three depicts the factors associated with positive and negative outcomes at one and six months post-injury; where post-injury negative and positive outcomes are defined as presence versus absence of post concussive symptoms. Finally, section four examines the accuracy of Servadei, et al.'s (2001) high, medium and low risk mild TBI categories in predicting who will develop PCS at one and six months post-injury.

SECTION 1: Incidence of Mild TBI

The following section presents the incidence of mild TBI in the Waikato and Hamilton regions of NZ. These are presented per 100,000 populations in order to allow comparisons. First, overall incidence by ethnicity for Māori and Non-Māori ethnicity is presented, this is followed by incidence by severity of mild TBI; by region; and finally by mechanism of injury. A number of figures are used to present this data. Please note that the scale of these figures is the same throughout to allow for better comparisons. For the purposes of incidence calculations, participants were allocated to either the Māori or Non-Māori group. Where they reported both being Māori and another ethnicity, they were classified as Māori, given this is NZ's indigenous population; in addition, this is done for comparison purposes, in line with NZ census data

protocols. Incidences are reported separately by ethnicity; as large disparity in ethnic incidence rates have been reported in previous studies such as Barker-Collo, Wilde, and Feigin (2008). Therefore this allows results to be compared to other published studies.

Incidence of mild TBI by ethnicity

There was wide disparity in the incidence rates according to ethnicity. The participants consisted of 30.9% Māori and 69.1% Non-Māori. The overall incidence of mild TBI for Māori was 1,026 per 100 000 population; with 1,408 and 700 per 100,000 for Māori males and Māori females, respectively. The overall incidence of mild TBI for Non-Māori was comparatively lower at 301 per 100 000; with 379 and 227 per 100,000 population for Non-Māori males and females, respectively. Figure 5 presents incidence rates by age and gender for both Māori and Non-Māori.

As can be seen in Figure 5, mild TBI in Māori males and Māori females followed a similar pattern; with peaks in the older age group of 75-79 years for Māori males and 80-84 years for Māori females. Incidence also peaked in three other age groups for both Māori genders; 20-24, 40-49, and 60-64 years. As noted above, Māori males showed a higher incidence than Māori females, with the exception of the 30-34, 55-59, 70-74, and 85 years and over age bands. However, these higher incidence rates in older age bands for Māori should be interpreted with caution due to small numbers of identified mild TBI cases and small population base numbers. For example, from the age of 50 years onwards, less than ten cases of mild TBI were indentified for males, and the same is true for age 55 years onwards. Incidence of mild TBI for Non-Māori peaked in the 85 years and over age group, with a steady increase from age 65 years. A smaller

peak was noted in the age group of 20-24 years. As with Māori, both genders following roughly the same trend, and males generally had higher incidences than females.

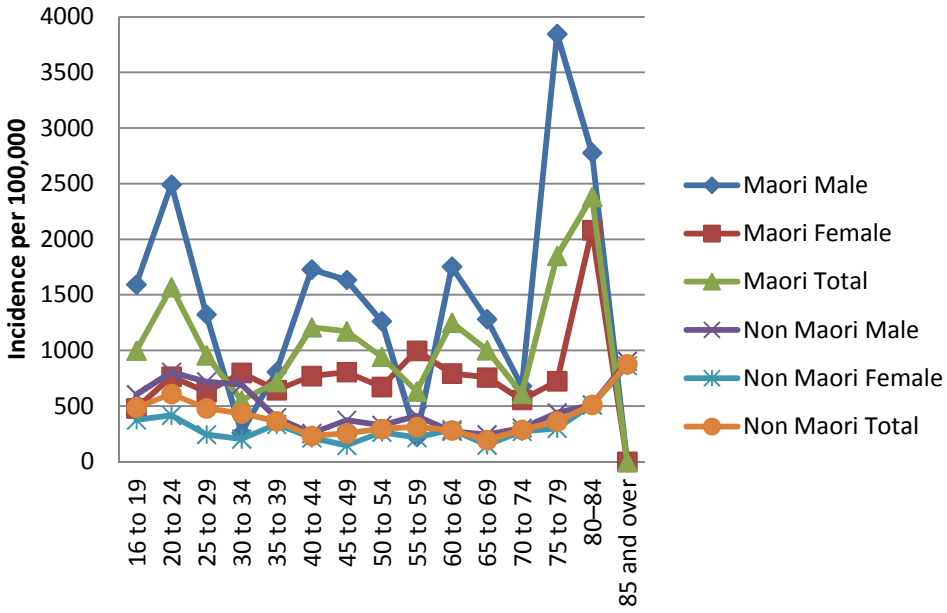

Figure 5. Incidence of all mild TBI by ethnicity across age and gender groups

Incidence of mild TBI by severity

The following section presents incidence by age and gender for the mild TBI severity categories suggested by Servadei, et al. (2001). Mild low risk TBI accounted for 22.4% of the total sample, 21.7% were in the mild medium risk group, and 55.9% were in the mild high risk group. Given the wide disparity between Māori and Non- Māori incidence noted above, this was also done by ethnicity. Overall incidence per 100 000 population was 102 for mild low risk TBI, 98 for mild medium risk, and 253 for mild high risk. Incidence by age band, ethnicity, and gender for the mild low, medium and high risk groupings are presented in Figures 6-8.

Incidences of the mild low risk group per 100 000 was 287 for Māori males, 187 for Māori females, 233 for total Māori, 87 for Non-Māori males, 45 for Non-Māori females, and 65 for total Non-Māori. As shown in Figure 6, incidence of mild low risk TBI for Māori males and

Māori females followed a similar trend between the ages of 25-74 years with peaks in age 45-54 years and a smaller peak in age 60-64 years. Māori males also peaked in the age of 20-24. Māori females had the highest peak in 75-79 years. Incidence for non-Māori remained relatively low for males (0 to 185 per 100 000 population) and females (0 to 104 per 100 000 population) across age bands.

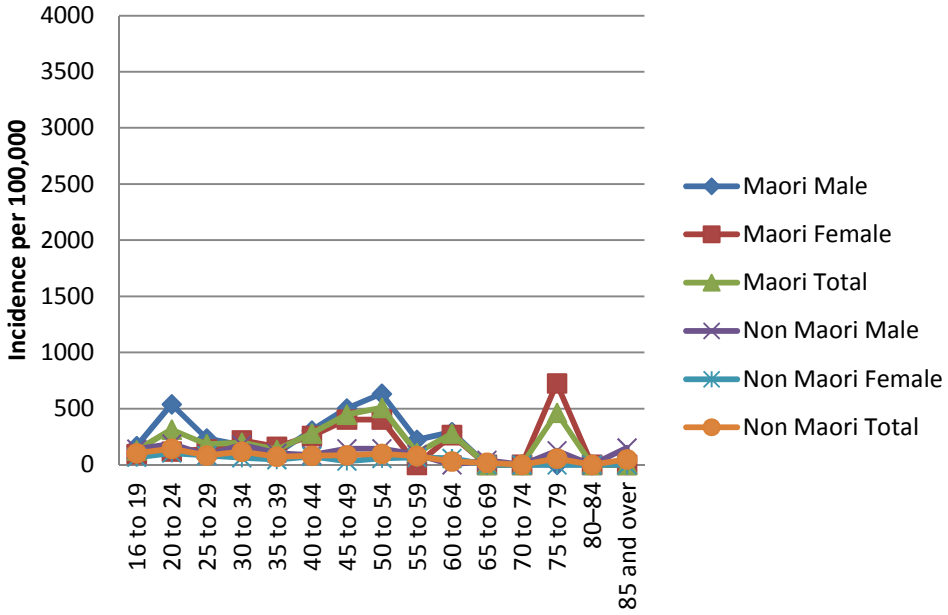

Figure 6. Incidence of mild low risk TBI by ethnicity across age and gender groups

Incidences for the mild medium risk group was 278 for Māori males, 106 for Māori females, 185 for total Māori, 86 for Non-Māori males, 53 for Non-Māori females, and 69 for total Non-Māori. As shown in Figure 7, Māori males and females follow roughly a similar trend; with incidences of mild medium risk TBI in the age of 20-29 years, and 60-64 years showing particularly visible peaks for Māori males. Incidences for Non-Māori are considerably lower with a decline across age ranges for both males and females.

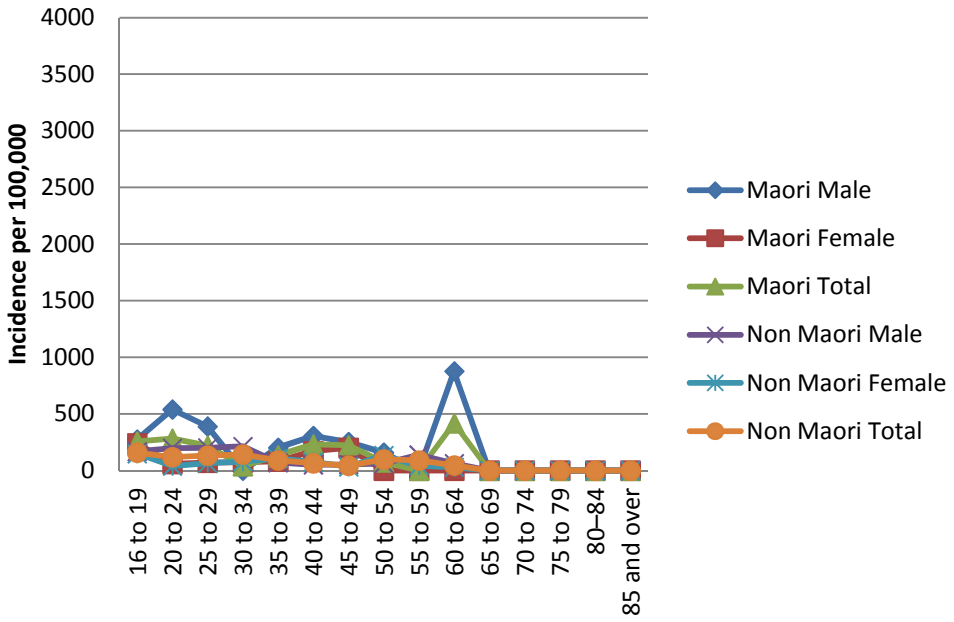

Figure 7. Incidence of mild medium risk TBI by ethnicity across age and gender groups

Incidences for the mild high risk group were much higher than that of the other two severity groups. Incidence per 100 000 was 843 for Māori males, 407 for Māori females, 607 for total Māori, 206 for Non-Māori males, 130 for Non-Māori females, and 167 for total Non-Māori. The highest incidence was for Māori males in the age of 75-84 years. There were several other peaks for this group (age 16-24 years, 40-49 years, and 65-69 years). There were also a number of peaks for Māori females, with the highest peak in the older age group of 80-84 years, and smaller peaks from 20-44 years, and 55 4 years. The pattern for both genders for Non–Māori was similar, with a peak in age 20-24 years, and a steady increase in incidences from age 60 years onwards, the highest incidence in was in the oldest age range of 85 years and over.

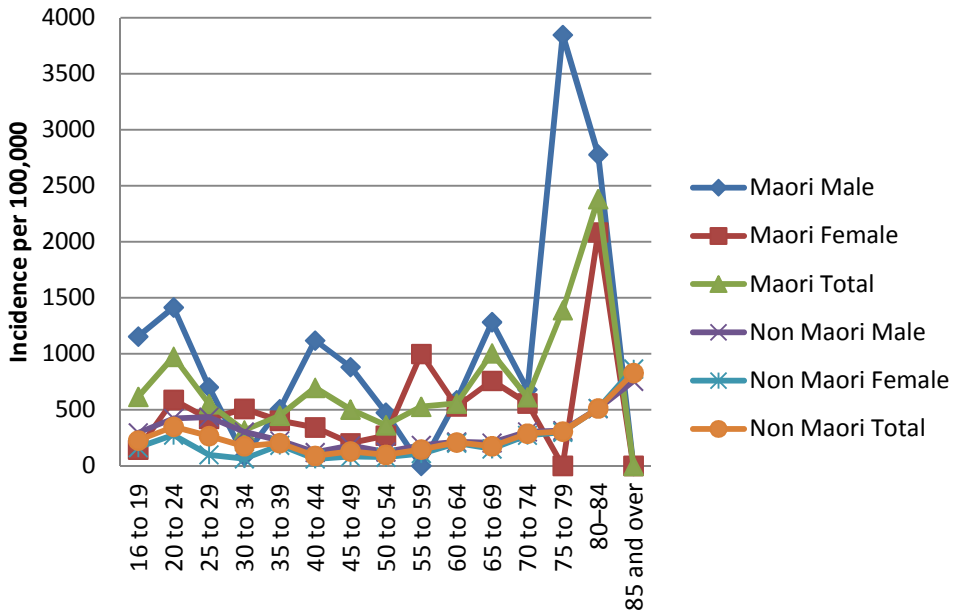

Figure 8. Incidence of mild high risk TBI by ethnicity across age and gender groups

In summary, incidence of mild TBI was highest in the mild high risk TBI group for both ethnicities and genders; though the patterns of incidence differed considerably between Māori and non-Māori. Māori males have the highest incidence of mild TBI of all severities compared to Māori females and Non-Māori males and females. While Māori tend to have peaks in incidence in the early, middle and late age bands; incidence for non-Māori only showed a noticeable increase for high risk injury in those over the age of 85 years.

Incidence of mild TBI by area of residency

The following section presents incidence by age, gender and ethnicity for mild TBI according to region. In this context Hamilton city is considered an urban area whereas the Waikato region is considered a rural area. The majority of participants were residents of Hamilton (75.1%) and 24.9% were from Waikato. As can be seen in Figure 9, the incidence of mild TBI for urban participants is more than twice as high at 704 per 100,000 population

(Māori) and 234 (Non-Māori) compared to rural participants, whose incidence was 321(Māori) and 66 (Non-Māori) per 100,000 population. There is a peak in incidence of mild TBI for urban Non-Māori participants aged 85+ years, but not for rural participants. The incidence of mild TBI for urban Māori males peaked in those aged 75-79 years, while for Māori females this occurred in those aged 80-84 years. Both genders follow a similar trend across age groups for Māori participants. The highest incidence is in the 85+ years for both genders in the Non-Māori groups.

The incidence of mild TBI for rural Māori of both genders is highest in the 80-84 years age group. The rural incidence of mild TBI is similar across the age groups for Non-Māori for both genders.

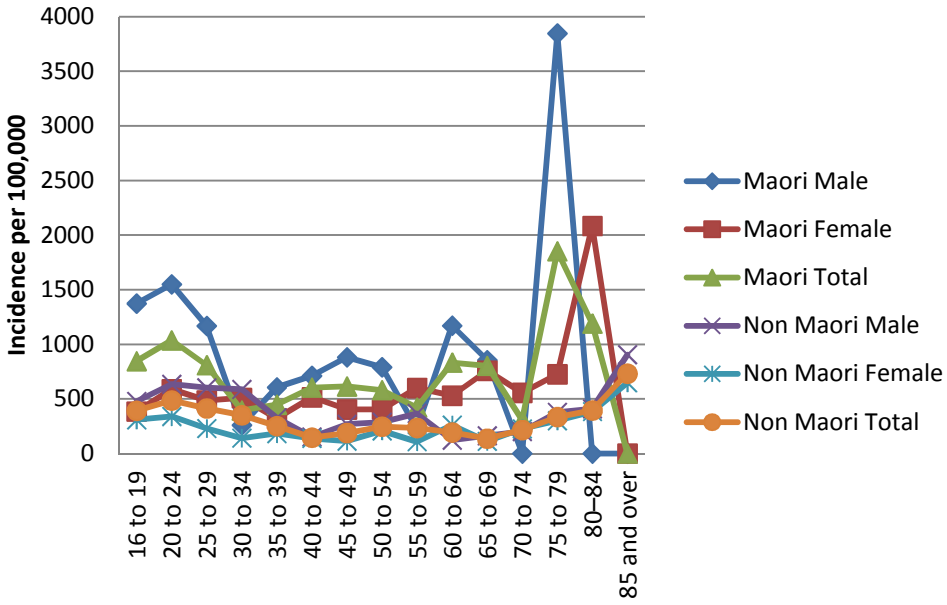

Figure 9. Incidence of mild TBI by ethnicity across age and gender groups for urban participants

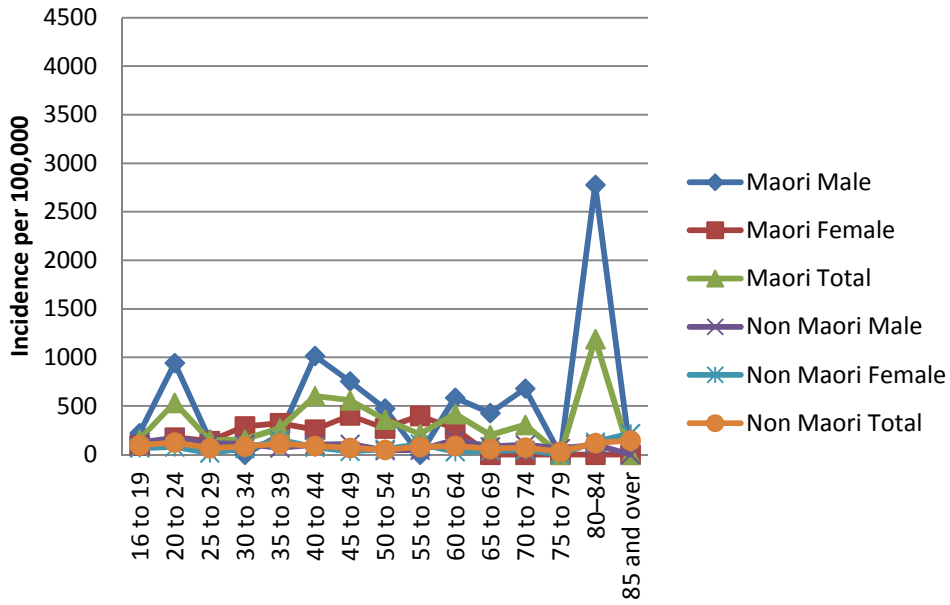

Figure 10. Incidence of mild TBI by ethnicity across age and gender groups for rural participants

Incidence of mild TBI by mechanism of injury

The following section describes the incidences of mild TBI by mechanism of injury. As can be seen below, the most common cause of mild TBI for the overall sample and Non Māori participants were falls, followed by assault, traffic, recreational activities, others, and industrial injuries. The causes for Māori participants were different to this, with assault being the most common cause, followed by falls, traffic, others, recreational activities, and industrial injuries. As can be seen in Figure 11, which presents the overall incidence by mechanism across age bands, there are age specific differences in incidence, with assault clearly showing the highest incidences of overall mild TBI in the younger age groups of 16-35 years. After age 39, however, falls had the highest incidence. Industrial accidents had the lowest incidence at every age, and incidence of recreational injuries showed a noticeable drop after age 34 years. The following sections will describe mechanism specific incidence patterns.

Table 8

Mechanism of injury by ethnicity

	MVA		Fall		Industrial		Recreational		Assault		Other		Total
	N	%	N	%	N	%	N	%	N	%	N	%	N
Non Māori	86	16.6%	195	37.6%	8	1.5%	64	12.3%	89	17.1%	77	14.8%	519
Māori	37	15.9%	56	24.1%	7	3.0%	21	9.1%	89	38.4%	22	9.5%	232
Total	123	16.4%	251	33.4%	15	2.0%	85	11.3%	178	23.7%	99	13.2%	751

MVA: Motor vehicle accidents

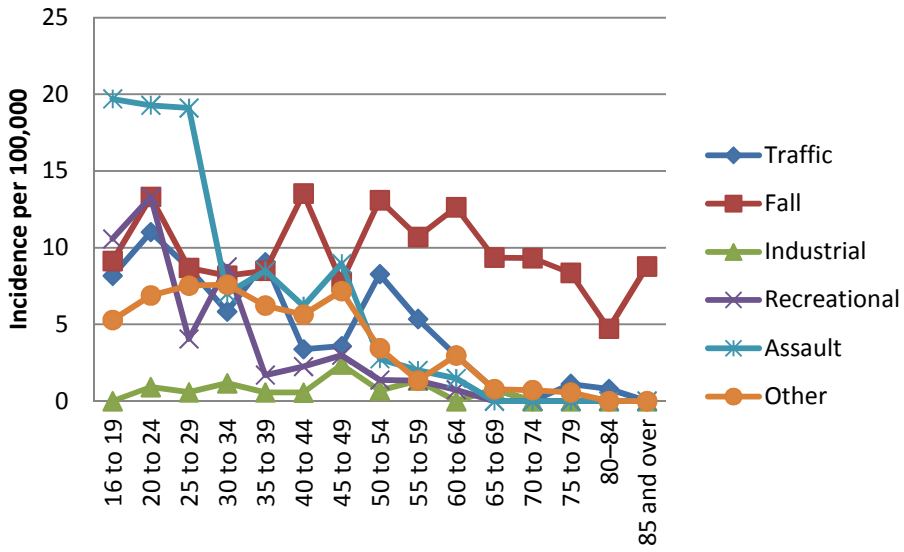

Figure 11. Incidence of Mild TBI by mechanism of injury across age groups

Traffic accidents

The incidences of mild TBI caused by traffic accidents per 100 000 was 239 for Māori males, 98 for Māori females, 163 for all Māori, and 70 for Non-Māori males, 30 for Non-Māori females, and 50 for total Non-Māori. As can be seen in Figure 12, Māori males have higher incidences compared to Māori females and Non-Māori participants for all age groups except 80-84 years where Māori females had the highest peak. Māori males showed several peaks in the

age groups of 20-24, 35-39, 50-54 and 65-69 years. Māori females also had a peak in incidence in the 50-54 age range. Non-Māori had comparatively lower incidences across the age groups, particularly for females.

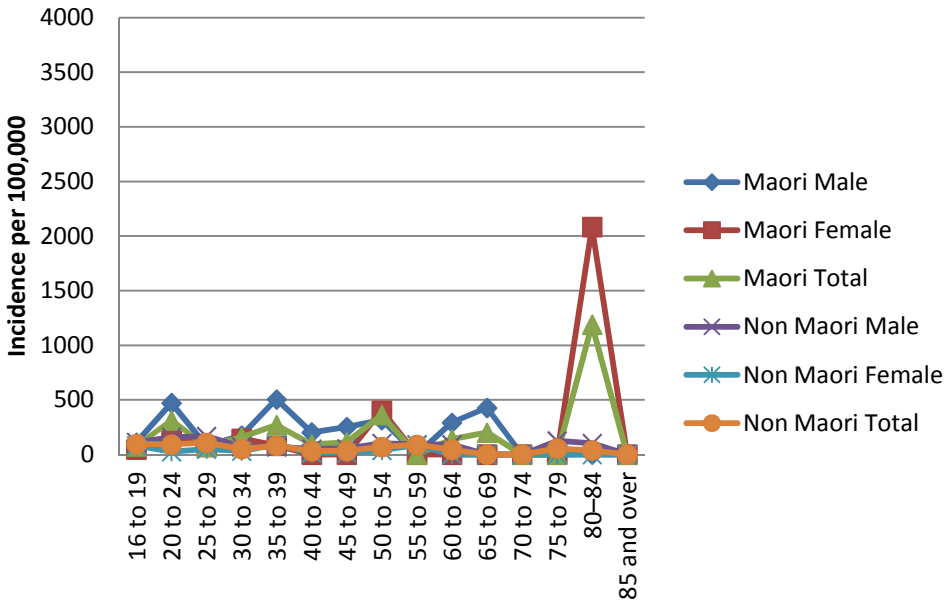

Figure 12. Incidence of all mild TBI due to traffic accidents by age, gender and ethnicity

Falls

The incidences of mild TBI caused by falls per 100 000 was 278 for Māori males, 220 for Māori females, 246 for all Māori, and 105 for Non-Māori males, 120 for Non-Māori females, and 113 for total Non-Māori. The incidence remained high for all age groups as can be seen in Figure 13. As for age and ethnicity specific incidences shown in Figure 13, Māori males has the highest incidence of mild TBI, particularly in the older age groups, 75-84 years, and also peaks in age 40-44, 50-54 and 60-64. The incidence of mild TBI for Māori Females steadily increased from the age of 55 to 79 years, with no incidences in those older than 80 years. The incidence of

mild TBI for Non-Māori of both genders steadily increased from the age of 65 years, with the highest incidence in those aged 80 - 85 years.

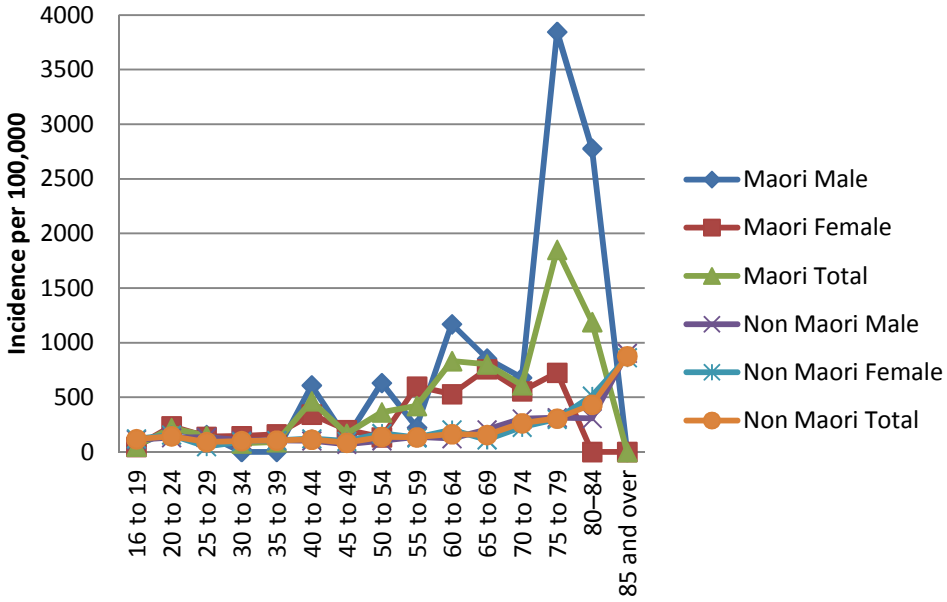

Figure 13. Incidence of all mild TBI due to falls by age, gender and ethnicity

Industrial injuries

The incidences of mild TBI caused by industrial injuries per 100 000 was 16 for Māori males, 31 for Māori females, 48 for all Māori, and 0 for Non-Māori males, 5 for Non-Māori females, and 10 for total Non-Māori. The incidences of mild TBI caused by industrial injuries are lowest in comparison to other causes. As can be seen in Figure 14 which presents incidences of mild TBI caused by industrial injuries, both Māori male and female have higher rates in the age groups of 45-49 years. Incidence of mild TBI for Non-Māori males peaked in the age groups of 30-34, 50-55, and 65-69 years. Incidence of Non-Māori Females was low across all age groups.

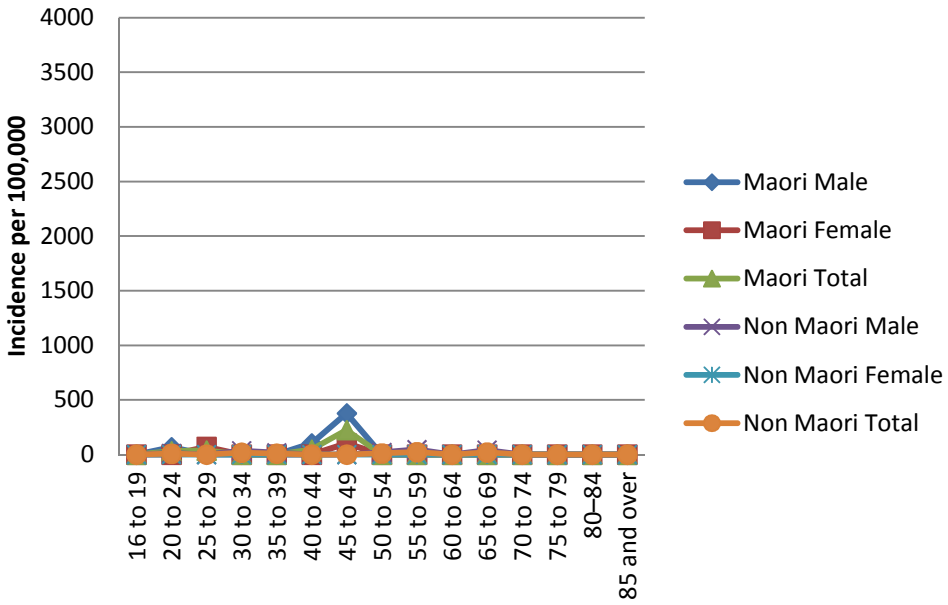

Figure 14. Incidence of all mild TBI due to industrial causes by age, gender and ethnicity

Recreational injuries

The incidences of mild TBI caused by recreational injuries per 100 000 was 153 for Māori males, 81 for Māori females, 114 for all Māori, and 57 for Non-Māori males, 18 for Non-Māori females, and 37 for total Non-Māori. Incidences peaked at age 16 -24 years and 30-34 years as shown in Figure 15. As can be seen in Figure 15 which presents the incidence of mild TBI caused by recreational injuries, Māori males have higher rates, with the highest peak in the age group of 75-84 years, and several other peaks in the age of 40-44, 50-54, and 60-64 years. As for Māori females, it peaked in the age of 55 -79 years. The incidences for Non-Māori of both genders began to steadily increase from the age of 65 years, with the highest incidence in the 85years and over.

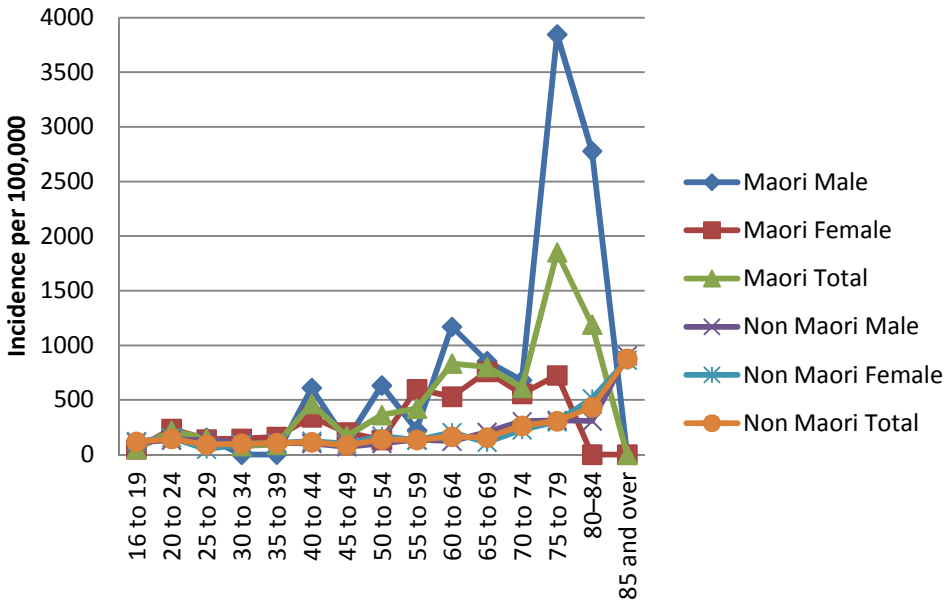

Figure 15. Incidence of all mild TBI due to recreational causes by age, gender and ethnicity

Assaults

The incidences of mild TBI caused by assaults per 100 000 was 594 for Māori males, 220 for Māori females, 392 for all Māori, and 79 for Non-Māori males, 26 for Non-Māori females, and 51 for total Non-Māori. Assault is the most common cause of mild TBI in the younger groups between 16-29 years as shown in Figure 16. It dropped in the age range of 30 -34 years, however continued to be the second most common cause of mild TBI. The incidence steadily declined from age 50 years onwards. As can be seen in Figure 12 which presents the incidence of mild TBI caused assaults, the highest incidences are for Māori males aged 16-29 years, followed by 40-54 years, and 60-64 years. As for Māori females, the incidence steadily increased from age 16 years, reaching a peak at age 35-39 years; it dips slightly in ages 40-44 years, with another peak at age 45-49; and it peaks again in age 55-59 years.

The incidence of mild TBI caused by assaults in Non-Māori follows a similar trend for both genders, although males had higher incidences for all age groups, both genders had higher

incidences in the younger age groups from age 16-29 years, with another peak for males aged 45-49 years.

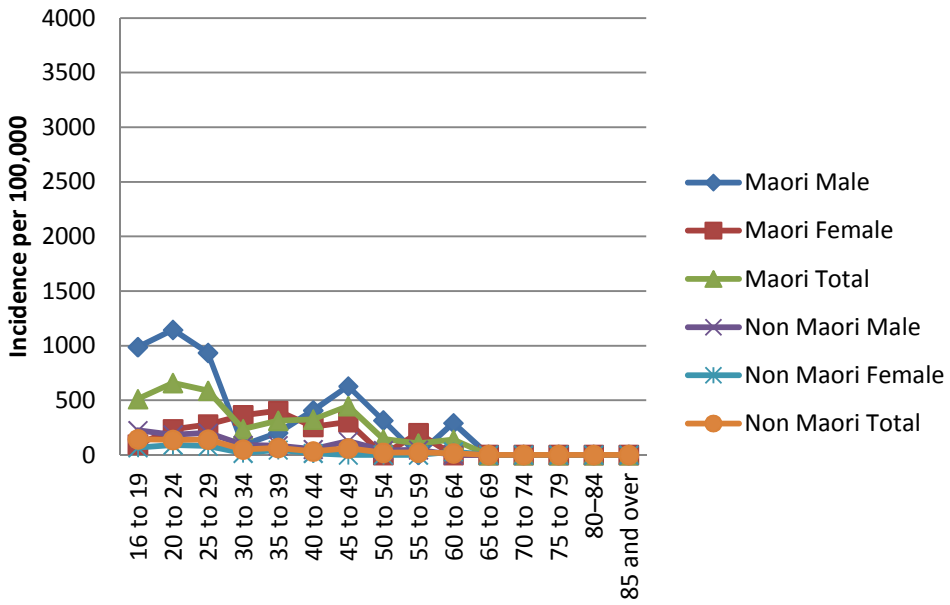

Figure 16. Incidence of all mild TBI due to assaults by age, gender and ethnicity

Other causes

The incidences of mild TBI by other causes per 100 000 was 96 for Māori males, 98 for Māori females, 97 for all Māori, and 56 for Non-Māori males, 34 for Non-Māori females, and 44 for total Non-Māori. As can be seen in Figure 17, incidence of mild TBI by other causes, Māori females has higher incidences with peaks in age 16-19 years, 40-54 years and again in age 60-64 years.

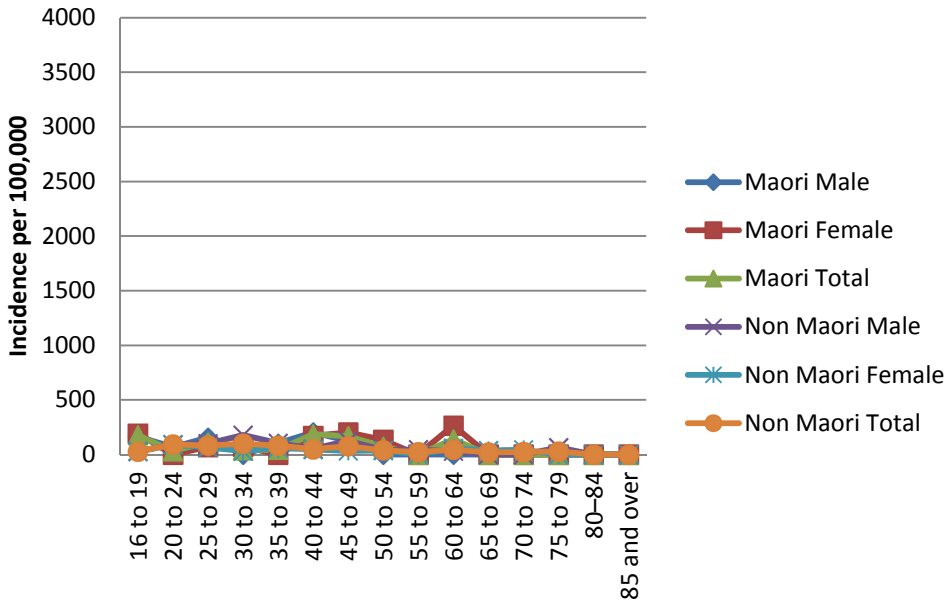

Figure 17. Incidence of all mild TBI due to other causes by age, gender and ethnicity

Summary

In summary, mild TBI incidences was much higher in Māori than Non-Māori, and was particularly high in Māori Males regardless of injury severity, region or mechanism of injury. Incidence for mild TBI was higher in urban compared to rural populations, again with Māori more at risk than Non-Māori, with the highest incidences in Māori males. The most common severity of injury was mild high risk. As for incidence of mild TBI by mechanism of injury, the highest incidences are due to falls and recreational injuries across age groups, with higher incidences caused by traffic accidents in the younger age groups. Māori also have higher incidences than Non-Māori regardless of mechanism of injury. Despite these statistics, caution should be made in generalising higher incidences of mild TBI in Māori, particularly for the older age bands given small population numbers in these age bands, and subsequently small numbers of mild TBI cases in these age bands.

SECTION 2: Outcomes of Mild TBI

This section examines overall performances on measures of psychological and social functioning; overall recovery, health related quality of life functioning; as well as performance on tests of cognitive functioning for the three assessment time points (baseline, one month and six months). Comparisons were made between baseline, one month and six month follow-up performances on the same measures. Table x below shows the means and standard deviations across all measures at each assessment time points, as well as the significance of within subject change on each test from baseline to one month, and from one to six month follow-up.

Psychological and Social Functioning

As can be seen in Table 9 below, anxiety and depression scores at all three assessment time points were within the "normal" range. Anxiety at baseline was however approaching the cut off point. Anxiety levels were higher than depression levels at each assessment time point. As for the changes overtime, the mean anxiety and depression scores decreased significantly from baseline to one month follow-up. While depression continued to decrease significantly from one to six months post-injury, a non-significant increase in anxiety was noted over this time frame.

The CIQ was conducted to measure community integration and social functioning. Scores were compared to those reported for mild TBI patients at three months post-injury by Stålnacke (2007), as no similar data are available for six months post-injury The mean Home Integration subscale score (4.76) at baseline indicates that the majority of the tasks in the home arena were "done by someone else", suggesting low integration. However at one (5.05) and six month (5.31) follow ups, on average the tasks were performed by "either the participant or someone else", indicating a moderate level of integration. These score are considered low, compared to

that (5.76) reported by Stålnacke (2007) for mild TBI patients in his study. The mean Social Integration score indicates that tasks were completed "both by participants and someone else, a moderate level of integration (8.89, 8.89, 8.92) for baseline, one and six month respectively. Again these are considered low compared to those (9.26) reported by Stålnacke (2007). The mean Productivity Integration score suggests that on average, participants were "either attending school full-time or working full time", moderate level of integration (4.66, 4.68, 4.87) at the three time points respectively, which are considered comparatively low scores compared to that reported by Stålnacke (2007).

The mean total CIQ score increased significantly from baseline to one month; meaning there is more integration into their community and home environment initially; while there was a further, though non-significant, increase from the one to six month follow ups. As for the subscale scores, participant's level of involvement in household tasks (i.e., Home Integration) increased significantly from baseline to one month, with a non-significant increase from the one to six month was noted. There were no changes in the participants' level of engagement in financial responsibilities and social activities (i.e., Social Integration) from baseline to one month and only a non-significant slight increase from one month to six month. There were slight non-significant increases in the participants' employment/educational involvements (i.e., Productivity Integration) over time.

As for perceived functional social support measured by the FSSQ, participants rated the level of support to be between "almost as much as they would like" and "not quite as much as they would like" across the three assessment time frames. On average, they perceived a slight increase in the amount of support initially, as indicated by a non-significant increase in the FSSQ score from baseline to one month, while there was a non-significant decrease in the mean score

from the one to six month time frame, suggesting they received less support they would like after their initial month of recovery.

The symptoms commonly experienced following a mild TBI were captured by the RPQ, participants' rated symptoms on this measure on average to be between being "no more of a problem" to being "a mild problem" at baseline. By six months, they indicated that it was between "not experienced" and "no more of a problem". They indicated that the presence and severity of these symptoms to reduce significantly over time; from baseline to one and from one to six months post-injury, suggesting a reduction in the severity of the symptoms.

Health Related Quality of Life

HRQoL was measured by the RAND 36-Item Health Survey. The subscale mean scores for the Physical Functioning , Role Emotional, Emotional Wellbeing and General Health were within 1 SD above the mean at all assessment time points, meaning the participants indicating slightly better functioning in these areas compared to the norm. The scores for Role Physical and Social Functioning were within 1 SD below the mean at baseline and one month, where they were functioning slightly less well compared to the norm; and within 1 SD above the mean at six month; functioning slightly better than the norm. The mean score for VT was within 1 SD below the mean at baseline, and within 1 SD above the mean at one and six months. The mean score for Bodily Pain was within 1 SD below for all three time points, suggesting that participants were performing slightly less well compared to the norm in this area.

The subscale mean scores for Physical Functioning, Role limitations due to physical health, Energy/fatigue level, Social Functioning, and Pain level, all increased significantly over time, indicating a reduction in the severity of these symptoms. As for Role limitations due to

emotional problems and Emotional well-being, although the mean scores appear to increase over time, this change was only significant from the one month to six month follow up. There were no significant changes in General health over time.

Cognitive Functioning

Cognitive functioning was measured using the CNS-VS test. At baseline, on average, participants' memory functioning measured by the Composite Memory and Visual memory scores fell within the average range, indicating normal functioning or capacity. Their scores in the majority of scales, including: Neurocognitive Index, Verbal Memory, Processing Speed, Executive Function, Psychomotor Speed, Reaction Time, and Cognitive Flexibility fell within the low average range, indicating slight deficit and slight impairment in these areas. Whilst Complex Attention fell in the low range, indicating moderate levels of deficit and impairment.

At one month post-injury, on average they were functioning in the average range for Visual memory, Processing Speed, Executive Function, and Cognitive Flexibility. However their functioning remained in the low average range for the Neurocognitive Index, Composite Memory, Verbal Memory, Psychomotor Speed, Reaction Time, Complex Attention.

At six months average functioning for the participants was in the average range for Composite Memory, Verbal Memory, Visual memory, Processing Speed, Executive Function, Psychomotor Speed, Reaction Time, and Cognitive Flexibility. Neurocognitive Index remained in the low average range. However, Complex Attention fell into the Low range. Of note, is that although their scores fell within the average range, it was on the lower end of the average range, within one SD below the mean.

The mean scores for Processing Speed, Executive Function, Psychomotor Speed, Reaction Time, and Cognitive Flexibility increased significantly over time, indicating an improvement in their functioning in these areas. As for the Neurocognitive Index mean score, it also improved over time, however this change was only significant from baseline to one month follow-up. The mean score for Composite Memory decreased significantly from baseline to one month, indicating a worsening in functioning in this area; while it improved from one month to six month, though non-significantly. The mean score for Complex Attention improved significantly from baseline to one month; but worsened from one month to six month, although this change was not significant.

The CFQ is a measure of self-reported memory and attention, and everyday errors in thinking. The mean scores at all three assessment time points suggest that participants rated their experiences of these problems to be between "very rarely" and "occasionally". The overall CFQ score showed non-significant changes over time, with the mean score increased initially, indicating a worsening in their functioning in this area; however it then remained almost the same from one to six months. Participants indicated that on average, they were having difficulties with memory and attention somewhere between very rarely and occasionally.

In summary, the results indicate that there were improvements in many areas of participants' functioning over time. These improvements were seen in participants' psychological functioning, community integration and HRQoL. Social functioning remained unchanged over time. As for cognitive functioning, significant improvements were noted initially from the baseline to one month follow ups in the majority of areas, except for Verbal Memory; however significant declines in functioning were also noted in the areas of Composite

Memory and Visual Memory. Improvements continued in all areas except Complex Attention from one to six months.

Table 9

Mean and Standard Deviations for measures conducted in baseline, one and six months; and changes over time

Variable	Baseline			1-Month post Injury			6-Months post injury			Change baseline to 1-month			Change 1-month to 6-months		
	N	Mean	SD	N	Mean	SD	N	Mean	SD	F	P	Parteta^2	F	P	Parteta^2
Emotional and Social Functioning															
HADS															
Anxiety	209	6.89	4.32	262	5.71	4.00	223	6.12	4.27	19.97	.000	.126	2.458	.119	.015
Depression	209	4.66	4.09	262	3.62	3.58	223	3.51	3.70	11.64	.001	.078	5.083	.026	.031
CIQ															
Home Integration	195	4.76	2.50	249	5.05	2.53	209	5.31	2.48	9.84	.002	.069	3.620	.059	.024
Social Integration	195	8.89	2.19	249	8.89	2.40	209	8.92	2.24	.784	.381	.006	.430	.513	.003
Productivity	195	4.66	2.04	248	4.68	1.97	209	4.87	1.90	2.67	.105	.020	3.130	.079	.021
Total CIQ	195	18.39	4.35	248	18.72	4.68	209	19.08	4.54	11.15	.001	.078	1.619	.205	.011
FSSQ	209	4.01	0.79	257	4.13	0.76	222	4.11	.82	3.71	.003	.064	.319	.006	.004
RPQ	196	18.73	15.01	258	15.09	14.33	213	13.24	15.01	31.19	.000	.188	17.667	.000	.104
Overall Recovery and HRQoL															
SF-36															
PF*	195	76.82	26.95	258	82.40	23.91	212	83.14	22.27	28.00	.000	.173	4.088	.045	.026

RP*	193	40.67	42.05	257	49.61	42.67	211	64.22	42.32	21.34	.000	.137	19.418	.000	.114
RE*	193	70.81	40.18	257	73.54	38.53	211	76.46	37.07	1.81	.181	.013	5.202	.024	.033
VT	193	49.77	24.09	258	55.18	22.62	211	58.81	23.48	41.19	.000	.235	8.422	.004	.053
MH	193	71.92	20.44	258	73.47	19.59	211	75.36	19.39	8.037	.005	.057	11.555	.001	.071
SF*	192	63.35	30.24	257	69.21	30.48	211	79.44	25.42	25.51	.000	.160	28.725	.000	.160
BP*	193	53.45	28.34	258	63.01	28.40	211	69.80	28.63	41.05	.000	.235	12.857	.000	.078
GH	195	66.44	22.19	258	66.10	22.82	212	67.50	23.02	.049	.825	.000	1.960	.164	.013
Cognitive Functioning															
CNS-VS															
Neurocognitive Index	154	83.62	24.33	216	88.30	21.72	159	89.29	23.10	20.06	.000	.163	.938	.335	.009
Composite Memory	156	91.87	18.95	218	87.95	21.13	159	90.97	19.29	5.71	.019	.052	.756	.386	.007
Verbal Memory	156	89.72	21.57	219	89.83	21.58	159	91.39	20.78	.449	.504	.004	1.508	.222	.014
Visual memory	156	96.14	16.94	218	90.96	18.46	159	93.96	16.67	11.65	.001	.102	.007	.933	.000
Processing Speed	162	87.96	19.06	223	90.30	18.68	161	91.74	18.83	12.58	.001	.102	6.603	.012	.057
Executive Function	161	84.11	26.50	223	92.88	22.91	160	94.68	22.28	43.86	.000	.283	7.602	.007	.065
Psychomotor Speed	162	86.60	20.83	223	89.87	21.89	161	92.68	21.03	25.24	.000	.185	7.835	.006	.067
Reaction Time	162	86.80	24.91	223	89.86	19.97	161	92.43	17.27	8.431	.004	.071	14.588	.000	.118
Complex Attention	158	70.41	66.99	221	80.33	55.28	160	77.39	70.43	9.40	.003	.079	.846	.360	.008
Cognitive Flexibility	159	81.94	28.65	223	90.98	24.81	160	92.64	24.13	44.15	.000	.286	4.748	.031	.042

CFQ	212	38.38	7.28	262	41.73	18.03	225	41.70	17.01	.003	.958	.000	3.267	.073	.020

CFQ: Cognitive failure questionnaire, FSSQ: Duke-UNC Functional Social Support Questionnaire, HADS: Hospital Anxiety Depression Scale, RPQ: Rivermead Post concussive Questionnaire, SF-36: RAND 36-Item Health Survey
PF: Physical Functioning, RP: Role limitations due to physical health, RE: Role limitations due to emotional problems, VT: Energy/fatigue, MH: Emotional well-being, SF: Social Functioning, BP: Pain, GH: General health
Part: Partial. Note N's for each measure include all individuals who completed that particular measure

SECTION 3: Factors associated with positive and negative outcomes

This section examines the factors associated with positive and negative outcome of mild TBI where this was defined as presence versus absence of PCS in accordance with the DSM-IV diagnostic criteria at one and six month post-injury. A variable was created to indicate presence versus absence of PCS using the RPQ. PCS was defined as per the DSM-IV criteria as the presence of at least three of the following symptoms (headache, dizziness, fatigue, irritability, sleep problems, affect changes, anxiety, or depression, changes in personality, and apathy). In this instance, three or more symptoms on the RPQ needed to receive a rating of 3 (a moderate problem) or 4 (a severe problem) to indicate presence of significant symptom. This section of the results examines the presence versus absence of PCS over time, and whether or not it was the same participants who met or did not meet criteria at both time frames (one and six month post-injury; as well as whether it is possible to predict presence versus absence of PCS at 6 months post-injury from characteristics of the individual and the injury at the time of injury, and outcome measures administered at baseline. It begins with a discussion of the number of participants with a presence and absence of PCS symptoms at one month post-injury and six month post-injury. This second aspect will include examining the degree and direction of relationships between performance on the RPQ and performance across measures at baseline. The results of this will be used to inform regression analysis to determine predictive ability of demographic factors and injury characteristics.

Performance on the RPQ

While the previous section presents performance and change in performance on the RPQ over time, this was in respect to the total scores. Here we look at presence versus absence of

PCS as defined above, and the changes over time in the proportion of individuals who would or would not meet criteria. As can be seen in Table 10, at baseline, those who reported PCS declined over the course of the study, though the proportion of individuals within the sample who met criteria for PCS at 6 months post-injury remained quite large.

Table 10

Frequency and percentages of reported absence versus presence of PCS at the three time points

	Baseline		1-Month Post-Injury		6-Months Post-Injury	
	N	%	N	%	N	%
PCS Present	84	52.50	92	45.77	61	40.13
PCS Absent	76	47.50	109	54.23	91	59.87
Total	160	100	201	100	152	100

PCS: Post-concussive syndrome

Using Chi Square analysis to compare absence versus presence of symptoms at baseline and 1 month follow-up, the results suggest a significant decrease in the proportion of individuals meeting PCS criteria (chi square [4] = 33.192, $p < .001$). As for one and six month follow-up, the results also suggest a significant decrease in the proportion of individuals meeting PCS criteria (chi square [4] = 53.628, $p < .001$).

The following section examines whether those who met or did not meet criteria for PCS are the same participants at one month and six months post-injury. As can be seen in Table 10, of those who reported the presence of PCS at one month, by six months 22 had symptoms that persisted, 21 reported an absence of symptoms by this time; indicating a large number of participants who experienced PCS at one month have symptoms that resolved by six months.

For those who reported an absence of PCS symptoms at one month, just over 11%reported presence of PCS at six months, with the remainder remaining symptom free or not completing the assessment. Thus, although there were some new cases, the majority remained symptom free at six months. Of those who developed PCS at six months post-injury, 25% had an additional TBI, possibly a trigger for PCS.

Table 11

The number and percentages of reported presence and absence of PCS at one month post-injury and changes at six month post-injury

		6 Months Post-injury PCS			
		Missing	Present	Absent	Total
1 Month Post-injury PCS	Missing	37 (38.54%)	31(32.29%)	28 (29.17%)	96
	Present	2 (4.4%)	22 (48.9%)	21 (46.7%)	45
	Absent	22 (30.6%)	8 (11.1%)	42 (58.3%)	72
	Total	61	61	91	

PCS: Post Concussive Syndrome

Predictors of performance at six months post-injury

A series of bivariate correlations was generated to examine the relationship between performance on the RPQ and injury characteristics at baseline. This included degree and direction of relationships with the RPQ total score and with presence versus absence of PCS at 6-months post-injury as measured by the RPQ. Variables of interests in relation to these outcomes include demographic variables (e.g., age, gender, ethnicity, area of residence, marital status, level

of education, pre-injury work status); injury related factors (e.g., GCS score, GOS score, ACC claim, intent, location of injury, mechanism of injury); and potential risk factors (e.g., alcohol use, drug use, co-morbid health conditions); and finally performance on measures of PCS, mood and social functioning, quality of life, and cognitive functioning at baseline. Pearson's correlations were generated for continuous variables, while Spearman's Rho was used for categorical data.

As can be seen in the table (Table 12) with Pearson's correlations, GOS; as well as performances on some measures at baseline (e.g., RPQ performance, FSSQ, CIQ, CFQ, HADs, CNS-VS, SF-36) were significantly correlated with performance on the RPQ at six months; with greater reports of PCS symptoms at 6 months linked to worse outcome on the GOS, reduced social support (FSSQ), decreased social integration (CIQ); reduction of quality of life (SF-36), and poorer neuropsychological performance (CNS-VS); and increased self-reports of depression and cognitive symptoms at baseline. Age, level of community integration overall and home integration in particular, and GCS at baseline, however, were not significantly correlated with performance on the RPQ at six months.

Table 12

Pearson's correlations between participants' demographics, injury characteristics and outcome measures at baseline and RPQ total score performance at 6 months

		Correlations with RPQ total score at 6 months	
		r	p
Demographics	Age at injury	.073	.291

Injury characteristics	Severity (Glasgow Coma Scale)	.112	.204
	Outcome (Glasgow Outcome Scale)	.359	.000**
Baseline Social and Mood functioning (FSSQ, CIQ, RPQ, HADS)	FSSQ total score	-.345	.000**
	CIQ Home integration score	.148	.141
	CIQ Social integration score	-.220	.027*
	CIQ Productivity score	-.242	.015*
	CIQ Total CIQ score	-.148	.140
	HADS-Anxiety score	.435	.000**
	HADS-Depression Score	.417	.000**
Baseline Cognition (CNS-VS and CFQ)	CNS Neurocognition Index Standard Score	-.382	.000**
	CFQ total score	.458	.000**
Baseline Health Related Quality of life (SF-36)	Physical	-.400	.000**
	Role limits Physical	-.203	.042*
	Role limits Emotional	-.347	.000**
	Energy	-.516	.000**
	Emotional	-.451	.000**
	Social	-.317	.001**
	Pain	-.317	.001**
	General	-.262	.008*

FSSQ: Duke Functional Social Support Questionnaire; CIQ: Community Integration Scale; RPQ: Rivermead Post-Concussive Questionnaire; HADS: Hospital Anxiety Depression Scale; CNS-VS: CNS Vital Signs Test; CFQ: Cognitive Failures Questionnaire; SF-36: RAND 36-Item Health Survey

*p<0.05

**p<0.01

As can be seen in Table 13 below, when performance at six months is defined as the presence versus the absence of PCS as defined using RPQ scores applied to DSM-IV criteria,

none of the variables tested (e.g., demographics, risk factors, injury characteristics, cause of injury variables) were significantly correlated with the RPQ.

When outcome at six month post-injury was defined as total RPQ score, possible predictors which were significantly correlated with this include gender, pre-injury work status, pre-injury smoking status, pre-morbid psychiatric illnesses, the Glasgow Outcome Score and activity of the participant at the time of injury.

Table 13

Spearman's Rho correlations between participant's demographics, risk factors, injury characteristics and performance on the RPQ at six months post-injury

		Correlations with RPQ performance at 6 months (Presence vs. absence of PCS)		Correlations with RPQ performance at 6 months (Total score)	
		r	p	r	p
Demographics	Area of Residence (Urban/Rural)	-.001	.985	.105	.127
	Gender (Male/Female)	.055	.424	.245	.000**
	Ethnicity (Māori/NZ European/Other)	-.035	.615	.101	.140
	Marital status (Married/Civil Union/De Facto; Separated/Divorced/Widowed; Never married/single)?	-.049	.480	.064	.361
	Pre-injury work situation (Full time paid work/Part time paid work/Retired/Unemployed or redundant/Beneficiary)	-.002	.982	.144	.038*
	Highest level of education (Primary School/High	-.013	.853	.036	.607

	School/Polytechnic/University)				
Risk factors	Smoking status (Never smoked, Ex smoker, Current smoker)	.037	.599	.169	.015*
	Previous head injury (Yes/No)	.054	.437	-.044	.523
	Previous psychiatric illnesses	-.034	.629	-.302	.000
Injury related characteristics	ACC Claim (Yes/No)	-.097	.179	-.075	.300
	Intent (Unintentional (accidental)/Intentional (self harm)/Intentional (assault/violence)/Suspected but not proven/Unknown)	.010	.887	.081	.238
	Glasgow Outcome Score (Dead/Vegetative state/Severely disabled/Moderately disabled/Good recovery)	.029	.678	.315	.000**
	Mechanism of injury (Traffic MVA/Fall/Industrial/Recreational/Assault/ Other)	-.065	.344	.029	.670
	Activity of at time of injury (Work/Leisure/Sport/Travelling/In a conflict situation/Other/Unknown)	.013	.856	.141	.040*
	Alcohol use (Yes/No)	.077	.263	.104	.129
	Drug use (Yes/No)	.037	.592	-.105	.126

MVA : Motor Vehicle Accidents; RPQ: Rivermead Post-Concussive Questionnaire;
*p<0.05
**p<0.01

As seen in previous paragraphs, demographic characteristics (e.g., gender, pre-injury work situation); risk factors (e.g., smoking status, pre-morbid psychiatric illnesses); activity at time of injury; and a number of outcome measures at baseline (e.g., GOS, HADS anxiety and depression, FSSQ, CIQ Productivity and CIQ Social Integration scores, SF-36, CFQ, and CNS-VS) were significantly correlated with PCS outcomes and are therefore potential predictors of

PCS at 6 months. In order to determine if each potential predictor is likely to share unique variance with PCS outcomes in regression analysis, multicolinearity of the potential predictors identified above was explored through generating correlations between the predictors. These are presented in tables 14 below.

Table 14

Pearson's correlations between potential predictors of PCS at 6 months post injury

	RPQ total score	GOS	FSSQ	CIQ SI	CIQ P	HADS Anxiety	HADS Depression	RPQ	CFQ	CNS Neurocognition Index	SF PHYSICAL	SF RL PHYSICAL	RL EMOTIONAL	SF ENERGY	SF EMOTIONAL	SF SOCIAL	SF_PAIN
GOS	.359**																
FSSQ	-.345**	-.031															
CIQ SI	-.220*	-.212**	.291**														
CIQ P	-.242*	-.352**	.123	.233**													
HADS Anxiety	.435**	.112	-.297**	-.070	-.096												
HADS Depression	.417**	.277**	-.358**	-.232**	-.248*	.610**											
RPQ	.603**	.337**	-.269**	-.209**	-.257*	.553**	.676**										
CFQ	.458**	.159*	-.178*	-.050	-.084	.563**	.536**	.617**									
CNS Neurocognition Index	-.382**	-.183*	.044	.311**	.120	-.158	-.243**	-.191*	-.187*								
SF PHYSICAL	-.400**	-.602**	.067	.325**	.469*	-.195**	-.418**	-.351**	-.157*	.189*							
SF RL PHYSICAL	-.203*	-.338**	-.011	.045	.228*	-.288**	-.433**	-.434**	-.173*	.062	.420**						
SF RL EMOTIONAL	-.347**	-.149*	.217**	.121	.182*	-.463**	-.533**	-.436**	-.247**	.102	.209**	.347**					

SF ENERGY	-.516**	-.294**	.336**	.174*	.264*	-.498**	-.688**	-.662**	-.470**	.082	.445**	.452**	.483**				
SF EMOTIONAL	-.451**	-.197**	.411**	.236**	.239*	-.695**	-.660**	-.548**	-.418**	.157	.260**	.287**	.575**	.662**			
SF SOCIAL	-.317**	-.442**	.130	.127	.271*	-.390**	-.550**	-.555**	-.315**	.034	.548**	.599**	.404**	.601**	.472**		
SF PAIN	-.317**	-.434**	.087	.138	.209*	-.411**	-.535**	-.510**	-.326**	.137	.495**	.619**	.302**	.516**	.387**	.625**	
SF GENERAL	-.262**	-.220**	.279**	.256**	.240*	-.367**	-.341**	-.333**	-.230**	.076	.400**	.256**	.283**	.459**	.461**	.330**	.383*

RPQ : Rivermead Post-Concussive Questionnaire; GOS: Glasgow Outcome Scale; FSSQ: Duke Functional Social Support Questionnaire; CIQ: Community Integration Scale; CIQ SI: CIQ Social Integration; CIQ P: CIQ Productivity ; HADS: Hospital Anxiety Depression Scale; CNS: CNS Vital Signs Test; SF: RAND 36-Item Health Survey

*p<0.05

**p<0.01

Table 15

Spearman's rho correlations between potential predictors of PCS at 6 months post injury

	RPQ total score	Residence	Gender	Age at injury	Ethnicity	Marital status	Pre-injury work situation	Education level	Smoking status	Previous head injury	Premorbid psychiatric illnesses	ACC Claim	Severity rating	Intent	GCS	GOS	Place of injury	Activity during injury	Mechanism of injury	Alcohol use
Residence	.105																			
Gender	.245**	.021																		
Age at injury	.120	.073*	.117**																	
Ethnicity	.101	.099**	-.020	-.082*																
Marital status	.064	-.126*	.025	-.501**	.155**															
Pre-injury work situation	.144*	-.130*	.170**	-.185**	.091	.311**														
Educational level	.036	-.088	.066	.007	-.106*	-.030	-.044													
Smoking status	.169*	.019	-.049	-.015	.178**	.052	.079	-.183**												
Previous head injury	-.044	.019	.104*	-.061	-.052	.004	-.048	.083	-.170**											
Premorbid psychiatric illnesses	-.302**	.020	-.218**	-.044	.125*	-.068	-.101*	-.069	-.081	.175**										
ACC Claim	-.075	-.121**	-.006	.007	.059	.035	.005	-.082	.100	.003	.019									
Severity rating	.038	-.039	.012	.081*	.022	-.081	.061	-.067	.122*	-.038	.041	.069								
Intent	.081	-.045	-.133**	-.246	.202**	.194**	.166**	.007	.146**	-.016	-.094	.046	.007							

GCS	.083	.050	.077	-.084**	.060	-.062	-.072	-.056	.054	-.005	-.022	-.042	-.344**	.074						
GOS	.315**	.031	.098	.203**	-.047	-.019	.035	-.041	.075	-.108*	-.128*	-.068	.072	-.127*	-.011					
Place of injury	-.110	.019	-.143**	-.156**	-.034	.016	-.145**	.058	-.146**	-.054	.079	-.058	-.136**	.057	.051	-.077				
Activity during injury	.141*	-.071*	.092**	.112**	.062	.119*	.266**	-.003	.138**	-.048	-.167**	.053	.020	.212*	-.059	.103*	-.231**			
Mechanism of injury	.029	-.079*	-.058	-.213**	.087*	.106*	.066	.048	.090	-.077	-.066	.005	-.052	.496*	.119**	-.195**	.122**	.018		
Alcohol use	.104	.043	.058	.152**	-.118**	-.181**	-.136**	.020	-.233**	-.010	-.028	-.120*	-.426**	-.200*	.070	.072	.157**	.073*	-.092*	
Drug use	-.105	-.021	-.021	.004	-.008	.108*	.013	.050	-.177**	.035	.033	-.057	-.214**	.108*	-.014	-.087	.177**	.184**	.027	.504**

RPQ : Rivermead Post-Concussive Questionnaire; ACC: Accident Compensation Corporation; GCS: Glasgow Coma Scale; GOS: Glasgow Outcome Scale

*p<0.05

**p<0.01

As can be seen in the Table 15 above, HADs Anxiety and Depression at baseline are significantly correlated, indicating multicolinearity, in examining the relationship between anxiety and depression with other predictors of interest, it can be seen that while anxiety does not significantly correlate with the CNS-VS, depression does. It was therefore decided that anxiety would be included in the regression instead of depression as it did not share significant variance with the other potential predictors.

CIQ Social Integration and CIQ Productivity scores at baseline were also significantly correlated, indicating multicolinearity, in examining the relationship between these scores with other predictors of interests, it can be seen that while Productivity does not significantly correlate with CNS-VS, Social Integration does, hence Productivity was included in the regression instead of Social Integration.

The CFQ was significantly correlated with all outcome measures; it was therefore excluded from regression analysis. Similarly, a number of SF variables (Physical, Role Physical, Role Emotional, Energy, Emotional, Social, Pain, General) at baseline were significantly correlated with each other indicating multicolinearity. All of the variables were also significantly correlated with other outcome measures, except Social and Pain, which did not significantly correlate with the CNS-VS, FSSQ and CIQ. As mentioned, SF Social and SF Pain were correlated, it was therefore decided that only one of these factors were chosen for regression analysis, given outcome measures for social functioning have been included, Pain was chosen over Social.

Given the above, gender, pre injury work situation, smoking status, self-reported pre-morbid psychiatric illness, the GOS, HADs Anxiety, FSSQ, CIQ Productivity Integration, CNS-

VS total, SF Pain at baseline assessment were included in the regression analysis described below.

Regression analysis with PCS total score as the predicted variable was conducted in two steps. In Step one characteristics of the individual prior to injury (gender, pre injury work situation, smoking status, pre-morbid psychiatric illness) were entered into the equation, while in step 2 performance on measures at baseline (GOS, HADs Anxiety, FSSQ, CIQ Productivity Integration, CNS-VS total, and SF Pain) were entered into the equation.

As can be seen in Table 16 below with Regression Analysis, with pre-injury factors (e.g., gender, smoking status, pre-injury work situation and the pre-morbid psychiatric illness) in the equation, prediction was significant at the .05 level. Contributing significantly was smoking status (p=.017, beta=.266). When performance on baseline outcome measures (HADS Anxiety, FSSQ, CIQ Productivity Integration score, CNS-VS neurocognitive index, and SF Pain) were added, prediction was significantly improved. Contributing significantly to prediction (as presented in Table 17 below) in this final model were gender (p=.033, beta=201), Glasgow Outcome Scale (p=.015, beta=.207), total score on the FSSQ (p= .009, beta=-.278), and the CNS-VS neuro-cognitive index score (p=.004, beta=-.289). Pre-injury factors accounted for 18.40% of variance in PCS outcome at six months post-injury, this improved to 33.30% with baseline measures added, accounting for 51.70% of total variance. In summary, female gender, poorer GOS, FSSQ, and CNS-VS performances at baseline were predictive of PCS at six months.

Table 16

Regression analysis

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	p
1	.429[a]	.184	.138	13.38166	.184	4.005	4	71	.005
2	.719[b]	.517	.442	10.76318	.333	7.458	6	65	.000

1.Pre-injury Predictors: pre-morbid psychiatric illness, smoking status, gender, pre-injury work status
2. Pre-injury and baseline outcome measures as predictors: pre-morbid psychiatric illness, smoking status, gender, pre-injury work status.
CIQ: Community Integration Questionnaire; CNS: CNS Vital Signs Test; FSSQ: Duke Functional Social Support Questionnaire; GOS: Global Outcome Scale: HADS: Hospital Anxiety and Depression Scale; SF-36: RAND 36-Item Health Survey

Table 17

Predictors of PCS outcomes at 6 months post-injury

Model		Unstandardised Coefficients		Standardized Coefficients	t	p
		B	Std. Error	Beta		
1	(Constant)	4.272	9.591		.445	.657
	Gender	5.923	3.153	.203	1.878	.064
	Pre-injury work status	.528	.619	.093	.852	.397
	Smoking status	4.629	1.899	.266	2.437	.017
	Pre-morbid psychiatric illness	-7.066	3.661	-.210	-1.930	.058
2	(Constant)	27.876	15.004		1.858	.068
	Gender	5.865	2.696	.201	2.176	.033
	Pre-injury work status	-.007	.516	-.001	-.013	.989
	Smoking status	.884	1.632	.051	.542	.590

Pre-morbid psychiatric illness	-3.570	3.204	-.106	-1.114	.269
GOS	9.239	3.697	.257	2.499	.015
FSSQ	-5.186	1.930	-.278	-2.687	.009
HADS-Anxiety	.713	.396	.199	1.801	.076
CNS	-.173	.058	-.289	-2.990	.004
CIQ Productivity score	-.937	.671	-.127	-1.396	.167
SF-36 PAIN	.065	.064	.115	1.022	.310

CIQ: Community Integration Questionnaire; CNS: CNS Vital Signs Test; FSSQ: Duke Functional Social Support Questionnaire; GOS: Global Outcome Scale: HADS: Hospital Anxiety and Depression Scale; SF-36: RAND 36-Item Health Survey

SECTION 4: Ability of Servadei, et al.'s (2001) high, medium and low risk mild TBI categories to predict who will develop PCS at one and six months post-injury

This final section examines the usefulness of Servadei, et al.'s (2001) proposed classification system for mild TBI in predicting outcomes. The first part of this section compares the number of those with and without PCS at one and six months as classified by Servadei, et al.'s (2001) mild TBI categories, followed by an examination of whether classifying mild TBI into mild low risk, mild medium risk and mild high risk TBI as proposed can accurately predict/distinguish those who will develop PCS at one and six months post-injury; where PCS presence/absence was measured using the RPQ, as mentioned in the previous section in the methods described. The second part looks at the usefulness of this classification system in predicting emotional, cognitive and functional outcomes at one and six months post-injury.

As can be seen in Table 18 below, at one month, slightly more participants reported an absence of PCS in both the mild low risk and mild high risk category; whilst about the same proportion of participants reported absence/presence of PCS in the mild medium risk group. By six months, more participants report an absence of PCS in all mild TBI categories.

Table 18

Percentage of participants displaying PCS at one and six months post-injury in each TBI sub-classification

Mild TBI sub-classification at baseline		1-month N (%)				6-months N (%)			
	N	Missing	PCS Present	PCS Absent	Total	Missing	PCS Present	PCS Absent	Total
Low risk	176	11 (33.30)	9 (27.30)	13 (39.4)	33	11 (36.70)	4 (13.30)	15 (50.0)	30
Medium risk	170	9 (16.10)	24 (42.90)	23 (41.10)	56	8 (19.0)	16(38.10)	18 (42.90)	42
High Risk	438	37 (21.90)	59 (34.90)	73 (43.2)	173	42 (29.80)	41 (29.10)	58 (41.10)	141
Total	784								

PCS: Post concussive syndrome

As can be seen in Table 19 below, Pearson's correlations were generated for RPQ total scores at one and six months with Servadei et al.'s (2001) mild TBI severity classification system, which show a non significant relationship. Spearman's rho correlations were generated for RPQ absence versus presence of PCS at one and six months, which again shows a non significant relationship with mild TBI severity sub-classification.

Table 19

Correlations (Pearsons and Spearmans) between PCS at 6 months and Servadei et al.'s (2001) mild TBI severity rating

		1 month		6 months	
		RPQ total score	RPQ absence vs. presence of PCS	RPQ total score	RPQ absence vs. presence of PCS
Servadei's mild TBI severity rating	Correlation value	r = .029	Rho = .033	r =. 080	Rho = -.040
	p	.648	.593	.245	.560

RPQ: Rivermead Post Concussion Questionnaire; PCS: Post concussive syndrome

A series of correlations were generated to examine the relationship between Servadei et al.'s (2001) mild TBI sub-classification system with measures of outcome of mild TBI at one and six months post-injury to examine its usefulness in predicting outcomes at one and six months post-injury using various outcome measures of emotional (HADs), cognitive (CFQ, CNS-VS), functional (CIQ, FSSQ) and quality of life (SF) in this population. As can be seen in Table 20 below, at one month post injury, there is a significant correlation with HADs depression score, CIQ total score, SF General Factor, CNS-VS Processing Speed, and CNS Psychomotor Speed. There is a trend towards significance for CNS-VS Executive functioning. By six months, this

classification system continued to be significantly correlated with the CIQ total score, and CNS-VS Processing Speed. In addition, it is significantly correlated with the CIQ Social Integration score and CIQ Productivity score; SF Pain factor; CNS-VS standard score and CNS Executive functioning. As well, there is a trend towards significance for SF Role Physical and CNS-VS psychomotor speed. Taken together this suggests that while Servadei, et al.'s (2001) categories are not helpful in determining likelihood of PCS after mild TBI, they are potentially useful in predicting short-term emotional, cognitive and functional outcomes of mild TBI.

Table 20

Correlations between performances on various outcome measures at one and six months with Servadei et al.'s (2001) mild TBI severity rating

Outcome measure	One month post-injury			Six month post-injury		
	N	r	p	N	r	p
HADS-Anxiety score	262	.035	.567	223	.040	553
HADS-Depression score	262	.159	.010	223	.074	.268
FSSQ Total score	257	.031	.617	222	-.001	.989
CIQ Home integration score	249	-.062	.329	209	-.069	.323
CIQ Social integration score	249	-.072	.255	209	-.206	.003
CIQ Productivity score	248	-.086	.175	209	-.161	.020
CIQ Total CIQ score	248	-.130	.041	209	-.188	.006
SF Physical	258	-.078	.211	212	-.122	.076
SF Role physical	257	-.063	.316	211	-.130	.059

SF Role Emotional	257	-.014	.820	211	.011	.871
SF Energy	258	-.084	.177	211	-.005	.944
SF Emotional	258	.020	.751	211	-.023	.736
SF Social	257	-.026	.683	211	-.041	.551
SF Pain	258	-.098	.118	211	-.162	.019
SF General	258	-.136	.029	212	-.068	.325
CNS Neurocognition Index	216	-.107	.117	159	-.225	.004
CNS Composite Memory	218	.018	.795	159	-.104	.190
CNS Verbal Memory	219	-.007	.922	159	-.125	.117
CNS Visual Memory	218	.032	.635	159	-.033	.677
CNS Processing Speed	223	-.159	.018	161	-.192	.015
CNS Executive Function	223	-.129	.054	160	-.202	.010
CNS Psychomotor Speed	223	-.148*	.027	161	-.152	.054
CFQ Total	262	.019	.758	225	-.044	.514

HADS: Hospital Anxiety Depression Scale; FSSQ: Duke Functional Social Support Questionnaire; CIQ: Community Integration Scale; SF: Short Form 36; CNS: CNS Vital Signs Test;
*P<.05
*P<.001

CHAPTER V: DISCUSSION

To our knowledge, this is the first large prospective population based study to investigate mild TBI incidence in adults. The primary goals of the present study were: (1) to determine the incidence of mild TBI over a one year period including age, sex, and ethnic-specific incidence in the Hamilton and Waikato districts of NZ, a region which is demographically representative of NZ's population; (2) to describe the psychological, psychosocial and cognitive outcomes of patients with mild TBI at 1 and 6 months post-injury; which is a period of rapid recovery; (3) to identify factors associated with positive and negative outcomes (defined as presence vs. absence of PCS in accordance with DSM-IV diagnostic criteria) at 6 months post-injury; and (4) to examine the accuracy of Servadei et al.'s (2001) high, medium, and low risk mild TBI sub-categories in predicting who will develop PCS at 6 months post-injury. A summary of each of the key findings pertinent to the primary goals and their relationship to the existing literature are presented below; followed by a discussion of the clinical implications of the findings; and finally the strengths and limitations of the current study will be explored, with recommendations for future research.

Mild TBI incidence

Our study revealed that there is a high incidence of mild TBI. The overall incidence for non-Māori was 301 per 100 000; with 379 and 227 per 100,000 population for males and females, respectively. The overall incidence rate and incidence rate for males are above the range expected by the WHO, while females are at the upper limits expected; where they reported annual incidences in the range of 100-300 cases per 100 000 (Cassidy, et al., 2004). This is also consistent with incidence rates reported by other published studies (Barker-Collo & Feigin,

2009; Cassidy, et al., 2004; M. Rapoport, S. McCullagh, D. Streiner, & A. Feinstein, 2003; Ryu, 2008; Torner & Schootman, 1996). However, many acknowledge this range may be an underestimate of the true incidence, because the majority of patients with mild TBI do not usually seek medical assistance, and hence are not captured in studies which are not population based. Thus, it has been estimated that the true incidence of mild TBI is more than 600 per 100 000 (Cassidy, et al., 2004); which, given the data from this study, would seem to be an overestimate of the problem. In the present study 23.5% of participants were not obtained through hospitals; a proportion which is lower than that anticipated by authors such as Cassidy et al. (2004).

However, higher incidence rates can be seen in NZ's indigenous people. For NZ's indigenous (Māori) people the overall incidence of mild TBI was 1,026 cases per 100 000 population; with 1,408 and 700 per 100,000 for Māori males and Māori females, respectively. Incidence rates for Māori were higher than Non-Māori for all age groups, in both rural and urban regions, and across mechanisms of injury, and severity of injury; reflecting wide disparity in incidence rates between ethnicities. This study is the first to report such high incidence rates; likely due to its population-based nature, which meant the inclusion of cases who did not seek medical attention. However, the incidence rates for Māori should be interpreted with caution, particularly for the older age bands as these may be significant due to small base populations.

The ethnic difference in incidence rates is not unexpected, and is consistent with the literature. The New Zealand Guidelines Group (2006, p. 138) states that the "incidence of mild TBI (14%) is under-reported in Māori". There are a number of explanations for this; in particular, Māori have been over represented in factors linked to higher rates of mild TBI, including lower socio-economic status, lower utilization of medical care, higher rates of

domestic violence, and higher rates of motor vehicle accidents. For example, Malcolm (1996) found that Māori and other New Zealanders in lower socio-economic status underutilised primary medical care, resulting in mild TBI not being captured in hospital based studies. Low socio-economic status has also been linked to higher rates of domestic and non-domestic violence and assaults in adults (Reiss & Roth, 1993). Indeed, the most common cause of mild TBI for Māori was assaults, accounting for almost 39% compared to only 17% in non-Māori; who's most common mechanism of injury was falls. Substantially higher rates of intimate partner victimization and perpetration, as well as higher rates of injury related to intimate partner violence have been reported by Māori compared to non-Māori (Marie, 2008). In Marie's report (2008), rates of intimate partner victimization in Māori were between 2.36 to 3.59 times higher than their non-Māori counterparts. Rates of convictions for male assaults on females is also considerably higher for Māori than for non-Māori (Hook, 2009).

SES has also been linked to poor outcomes of MVAs in minorities, partly due to lower rates of seat belt use and increased risk of accidents due to intoxication (Braver, 2003). Alcohol intoxication was indeed reported in this study, where alcohol use was indicated by 35% of Māori participants whose mild TBI was caused by a MVA, and only 18% in non-Māori. MVA were the third most common cause of mild TBI for both Māori and non-Māori.

In terms of incidence by mechanism of injury, unlike other studies, where MVA is the most common mechanism of mild TBI such as Kraus & Nourjah (1988); falls and assaults were more common for this sample. It might be hypothesized that MVAs often result in other injuries which are more likely to need medical attention, hence being captured in hospital based studies; whereas patients are more likely to not seek medical attention and carry on if their TBI was caused by a fall. It is also possible that this finding is reflective of assault being the most

common mechanism of mild TBI within the Māori sample, as discussed above. It is noteworthy that the majority of studies which report MVA as the most common mechanism of injury are from the United State, where litigation and compensation is often sought through the courts after an MVA; where another driver could be seen as at fault. In NZ, compensation for mild TBI is obtained through the government funded ACC, and is available regardless of the mechanism of injury.

Age specific incidence rates were bi-modally distributed by age, with the highest rates of injury occurring in those aged 15–24 years and those older than 65 years, which is consistent with Kraus and Nourjah's findings (1988). According to these authors the majority of TBI results are from motor MVAs, assaults, and falls (Kraus & Nourjah, 1988), the first of these two causes being more frequent in younger and urban dwelling persons and the third being more common among the elderly, which is a finding replicated by the present study.

Short term outcomes of mild TBI

A number of tools were used to measure emotional health, social functioning, health related quality of life, and cognitive functioning at one and six months post-injury. As for emotional functioning at baseline, the average anxiety level was approaching the cut-off point, suggesting mild anxiety and depression was within the normal range at baseline. Improvements were seen in participants' emotional functioning, with significant reductions in reported symptoms of depression from baseline to six month post-injury; and a significant reduction in feelings of anxiety from baseline to one month post-injury. This is contrary to reports in the literature, where the symptoms of mild TBI tend to change from somatic to psychological (Hall, et al., 2005), where more psychological symptoms are present over time. Depression and anxiety

have been found to be the most commonly reported psychological symptoms after mild TBI (Bryant, et al., 2010). However, it is important to note that the majority of studies which have reported psychological difficulties are studies comparing a mild TBI group to either a control group (e.g., F. C. Goldstein, et al., 2001) or other populations (e.g., Lange, et al., 2012; Levin, et al., 2001). Given this study does not have a control group; it is difficult to make comparisons. Secondly, it is worth noting that different measures are used in the literature for emotional wellbeing, again limiting the ability to draw comparisons across studies.

As for social functioning, the CIQ was used, which is a widely used measure in research for quantifying and measuring of rehabilitation outcomes in patients after TBI (Stålnacke, 2007). Interestingly, although participants' integration improved over time, they reported comparatively low community integration across the three time points. Participants in this study were found to have lower community integration in the areas of home, social and work arena as measured by the CIQ when compared to other mild TBI patients such as Stålnacke (2007) and Paniak, Phillips, Toller-Lobe, Durand, and Nagy's (1999) studies. This difference may be partly due to the timeframe of assessment, such that Stålnacke's study (2007) was for three years post mild TBI, although Paniak, Phillips, Toller-Lobe, Durand, and Nagy's (1999) study was within three weeks of injury. It may also be a result of the unique makeup of the study population, such as the inclusion of both urban and rural participants in this study, where perhaps community integration may be more difficult for those living rurally.

As for HRQoL at baseline, participants reported slightly lowered functioning compared to the norms in the areas of social functioning, as well as functioning due to physical limitations. There were significant improvements over the course of six months in the areas of Physical Functioning, Role limitations due to physical health, Energy/fatigue level, Social Functioning,

and Pain level. Role limitations due to emotional problems and Emotional well-being also improved significantly from one month to six months. Despite the term "mild", deficits in HRQoL in the acute phase is common as reported by other authors (e.g., Tomberg, et al., 2005). Therefore, these difficulties are not unexpected. Deficits across a number of domains including social, somatic or physical, and emotional wellbeing are well documented in the literature (Anderson, et al., 2006; Silver, et al., 2009), hence the term PCS to capture the symptoms in these areas.

In terms of cognitive functioning at baseline, participants had slight deficits in their overall level of neurocognition; as well as more specific, slight deficits in Verbal Memory, Processing Speed, Executive Function, Psychomotor Speed, Reaction Time, and Cognitive Flexibility; and moderate level of impairment in Complex Attention. This is consistent with the literature, where deficits in memory, attention and processing speed have been reported in a number of studies of mild TBI in the acute stage (Hall, et al., 2005; Kibby & Long, 1996; Landre, et al., 2006; Levin, et al., 1987; Mathias, et al., 2004; Ponsford, et al., 2000).

As for changes over time in cognitive functioning, results were mixed, with significant improvements noted from baseline to one month follow-up in the majority of areas, except for Verbal Memory. Improvements continued in all areas except Complex Attention from one to six months. This is consistent with findings from a meta analysis, where attention was the only cognitive domain to have an effect size greater than 0, however this was at three months post-injury (Binder, 1997). However, a significant decline was noted in Visual Memory functioning. This finding has been previously reported (e.g., Levin, et al., 1987; Miotto et al., 2010). Miotto et al. (2010) investigated the cognitive functioning of patients with mild to moderate TBI using a comprehensive protocol of neuropsychological tests. They found significant deficits of

immediate and delayed visual memory recall, amongst deficits in other domains including immediate and delayed verbal memory recall, verbal recognition, naming, verbal fluency and information speed. Further studies are needed to explore reasons for visual memory deficits. This may be due to the part of brain which is responsible for such functioning; newer neuroimaging devices may provide answers for this.

Predicting Post Concussive Syndrome after mild TBI

In order to identify factors associated with positive and negative outcomes at six months post-injury, PCS was examined as it is the most commonly reported outcome for mild TBI by researchers in the field. Over half of the participants reported symptoms consistent with DSM-IV diagnosis of PCS initially post-injury. As expected, the proportion of participants reporting PCS declined over time, from 52.50% at baseline to 40.13% by six months post-injury. A closer look at the data revealed that of those who reported PCS at one month post-injury, 46.7% of cases had resolved by six months. Of particular interest is that of those 11.1% (N = 8) who initially reported an absence of PCS at one month post-injury, who reported a presence of PCS by six months, indicating a proportion of participants who developing PCS during the six months post-injury. Reasons for this were explored, including the possibility that these participants had not yet recognized such symptoms given baseline assessments (within two weeks of injury) were conducted so close to the injury. Another possibility is of these participants having experienced subsequent TBIs. Indeed, 25% (N=2) of those who developed PCS at the 6-month assessment after reporting no PCS at baseline reported having experienced at least one additional TBI between one and six months post-injury follow-ups. Another possibility for the development of PCS is that other injuries and stressors may have occurred during this period which triggers post-

concussive symptoms. Therefore these are not the direct result of the mild TBI. Post-concussive symptoms are commonly found in the general population (Willer & Leddy, 2006) as well as other conditions, therefore other causes are likely. This will need to be explored further. Additionally, participants who have pre-morbid conditions are more susceptible to developing PCS when they are exposed to other stresses post-mild TBI if they have. It was confirmed that 25% (N=2) had a history of TBI prior to the incident TBI that resulted in their enrolment in the study, and 25% (N=2) had a pre-morbid psychiatric illnesses. However our results did not find pre-morbid psychiatric illnesses to be predictive of PCS. Another possible reason to report difficulties which has been extensively studied outside of NZ is the possibility of monetary incentives. In NZ this would involve ACC claims, of those who developed PCS at the 6-month assessment after reporting no PCS at baseline, 37.50% (N=3) confirmed no ACC claims, the remainder 62.50% participants in this group either had an ACC claim, or did not specify whether or not they had a claim; as NZ does not litigate, this is unlikely to be a contributing factor.

The study then attempted to establish potential predictors of PCS outcome at six months post-injury. Potential predictors included participant demographics, injury characteristics. Potential risk factors and outcome measures conducted at baseline were used for bivariate correlations to establish any relationships with PCS at six months post-injury. The results revealed that greater reports of PCS symptoms at six months were linked to worse outcome on the GOS, reduced social support (DUKE), decreased social integration (CIQ); reduction of quality of life, and poorer neuropsychological performance (CNS-VS); and increased reports of depression, anxiety and cognitive symptoms at baseline. Also significantly correlated with increased likelihood of PCS were female gender, lower pre-injury work status, pre-injury smoking, pre-morbid psychiatric illnesses and the activity of the participant at the time of injury.

Regression analyses were then conducted to establish predictive ability of each of these factors. Results indicate that female gender, poorer GOS outcomes, and worse social and neuropsychological functioning contributed significantly to prediction of PCS outcomes. These factors' contribution to the prediction was about the same, suggesting that no one factor predicted PCS better. Consistent with Meares et al. (2008) and Ponsford et al., (2012) pre-injury psychiatric disorder and being female were linked to PCS, although these studies looked at PCS one week post-injury, this current study found that this continued to be the case six months post-injury.

Like Ponsford et al., (2012) who looked at predictors of poor outcome post mild TBI, both pre-morbid psychiatric illnesses and post-injury anxiety were related to PCS at six months, however, unlike Ponsford et al. (2012) who found these factors to be the strongest predictors for persistent symptoms three months post-injury, our study failed to find that these factors were predictive of PCS outcomes at six months. Their study also found older age as a predictor in outcomes at three months; this was not found in our study. It is unclear as to what may have caused this. Upon review, there is a difference in terms of participants' age. That is, participants in our study on average are older with a mean age of 37 years ranging from 16 to 99 years compared to Ponsford et al.'s (2012) study where the average was 31 years ranging from 18 to 72 years. Secondly, Ponsford et al. (2012) had a much more stringent exclusion criteria, such that it excluded those mild TBI patients who used alcohol and substance at the time of injury, had a history of previous impairment, neurological illness, significant alcohol or drug abuse or other psychiatric impairment currently affecting daily functioning. The differences in participant profiles may contribute to this difference in finding. Consistent with their study, our study did not find education or history of previous head injury to be associated with PCS at six

months, in their case was one week or three months post-injury, and possibly these factors are predictive up to three months post-injury.

Predictive ability of Servadei, et al.'s (2001) sub-classification system for mild TBI outcomes

Servadei, et al.'s (2001) sub-classification system for mild TBI was examined in relation to its ability to determine which participants would develop PCS over time. At one month post-injury, slightly fewer participants reported a presence compared to the absence of PCS in both the mild low risk and mild high risk category; whilst about the same proportion of participants reported absence/presence of PCS in the mild medium risk group. By six months, more participants report an absence of PCS in all mild TBI categories, suggesting positive outcomes in all mild TBI participants over time.

These results indicate that Servadei, et al.'s (2001) categories were not helpful in determining likelihood of PCS at one and six months post-injury for mild TBI participants given its non-significant relationship with PCS at six months, suggesting that those with higher level of severity of mild TBI were not more likely to develop PCS at six month post-injury as hypothesized.

However, the results of correlation analyses suggest that this classification system is potentially useful in predicting emotional and health related quality of life functioning at one month post-injury; where higher level of mild TBI severity is linked to higher levels of depression, and poorer health related quality of life functioning. This classification system is also predictive of community and social integration and cognitive functioning at both one and six months post mild TBI, where higher level of mild TBI severity is linked to poorer community

integration, and worse processing speed. Those with higher levels of mild TBI were also more likely to experience more pain and reduced overall level of cognitive functioning at six months post-injury.

In summary, this classification system is predictive of emotional wellbeing, health related quality of life and cognitive functioning, but not PCS. Perhaps PCS is too broadly defined, as it captures emotional, cognitive and physical symptoms. Therefore, it is predictive of more specific functioning, such as those reported above. In order to use this classification system as a predictor for more specific outcomes, it needs to be tested further in future studies.

Clinical implications

Our findings suggest that the incidence of mild TBI in NZ is far greater than those reported in previous studies, particularly for the indigenous people of the country. When planning prevention and rehabilitation services, providers have to recognise and manage specific needs of these at risk populations such as Māori, the younger and older population. As recommended by the New Zealand Guidelines Group (2006), when dealing with Māori patients, providers need to be culturally sensitive and realise that the patient with TBI should not be considered in isolation, but take a holistic approach to his or her health to ensure optimal outcomes. The Guideline also recommends improving access for Māori to appropriate services, with the aim of improving overall Māori TBI outcomes. These recommendations are also relevant for other at risk persons identified in this study, such as males, the younger and older populations.

Given the high percentage of participants experiencing PCS, preventative measures such as the provision of educational materials on post concussive symptoms and coping strategies for such problems can be provided to equip mild TBI patients to look out for PCS and cope with

PCS should it arises. This approach have been found useful, where interventions with education and support have been linked to symptom resolution in some patients with uncomplicated mild head injury (e.g., Alves, et al., 1993). Information is available in the community; however accessibility of this information to all mild TBI patients is questionable. Where information is available, these do not appear to be provided consistently, or the content may be beyond the ability of the patient. For example, Moore and Leathem (2004) conducted a survey on GPs and hospital emergency departments to determine the nature, extent and quality of information provided to people after mild TBI. Of the 244 surveys returned, they found 42.8% of GPs and 93.4% of emergency department staff provided information sheets to patients with a confirmed or suspected mild TBI. Currently, there are limited guidelines, such as those set by ACC (e.g., New Zealand Guideline Group, 2006, 2007). However these are not specifically tailored for mild TBI patients, such guidelines would be useful for clinicians assessing mild TBI patients. The identification of such cases might allow early provision of management or rehabilitative services to reduce the development of ongoing problems. Additionally, as pointed out by Ponsford, et al. (2012), understanding the causes of ongoing PCS may also guide treatment. This study contributes to the current literature on potential predictors of PCS, where it is another step closer to identifying those at risk.

One of the hypotheses of this study was that the classification of mild TBI would be useful for predicting PCS, although this was not proven; Servadei, et al.'s (2001) sub-classifications of mild TBI was useful in predicting more specific symptoms including emotional wellbeing, health related quality of life, cognitive functioning and community integration. Therefore, this classification can potentially be used as a screening tool to screen those at risk of developing deficits in the areas, rather than PCS as a whole. In addition, it would be useful to screen and

monitor functioning in mood, cognitive functioning, pain level and community integration, given these are commonly displayed following a mild TBI.

Strengths and limitations

This study has a number of strengths: the population-based design with case ascertainment at a community level, the comprehensiveness (TBI ascertainment of data across age groups, mild TBI severities, ethnic origins, inclusion of urban and rural populations, and the large sample size allowed reliable subgroup analyses) and the use of standard criteria for defining TBI allows international comparisons; all make this a unique study in capturing the true incidence and outcomes of mild TBI. Additionally, comprehensive baseline assessments, and outcome assessments at one and six months allowed examination of the natural course of recovery across a number of outcome areas, contributing to current literature on outcomes at the sub-acute phase of injury. The methodologies selected for this study makes findings more generalisable compared to previous published studies which were mostly smaller scaled studies, had selection of convenience samples, and were often cross-sectional designs.

Method used for data collection was also carefully chosen. The assessment was done via questionnaires in the form of an interview. Iverson, Brooks, Ashton, and Lange (2010) compared spontaneous, open ended interview-based post-concussion symptom reporting to endorsement of symptoms on a standardized questionnaire. They found that their participants reported far more symptoms on the questionnaire than during an interview. The questionnaires are likely to remind the participant of a symptom, encourage them to report symptoms that they did not think were of interest. The method this study employed minimized this risk by having an interviewer present to aid comprehension of the statements and to clarify the instructions and

statements to minimize the risk of participants over or under endorsing symptoms. The questionnaires also allow participants who are not good at articulating their symptoms to still endorse them, as to avoid under endorsing in interviews.

Finally, there were no significant events such as earthquakes, which occurred during the year that were expected to impact the findings; therefore it is highly likely that these are true incidence rates of mild TBI. Given the true incidence rates of mild TBI was yet to be confirmed, this study gives an insight into the extent of this "silent epidemic".

However, there are some limitations with this study. Firstly, despite extensive efforts to capture all mild TBI cases, some cases might still have been missed, these likely to be the domestic and child violence cases.

Secondly, it was a challenge to use the GCS for mild TBI classification for participants with TBI who did not attend hospital and therefore did not have it recorded in their medical records. Where GCS was recorded in other settings such as private clinics, these were recorded. There is possible diagnostic bias of measuring GCS in those with mild TBI who are, for example, under the influence of recreational drugs, or who are unable to understand English. Fortunately, where feasible, interpreters were used to aid communication.

Thirdly, for those cases retrieved retrospectively from the search of national health databases (e.g., ACC), there is the additional limitation of a greater proportion of missing data, and potential introduction of information bias. However, we included few such cases (N=3), and thus the effect of this on our study is likely to be small. Additionally, post-concussive symptoms are present in the general population; hence the lack of healthy control sample limits natural changes over time.

In addition, without a control group for repeat testing or alternate measures, the effects of practice on the tests is unknown. All improvements that were present up to six months may have been the effect of practice.

Finally, there were no pre-injury measures of functioning, hence pre and post-injury functioning could not be compared. Pre-morbid functioning for such a large population is impossible, with a smaller scale study, pre-morbid functioning can be estimated, or alternatively a group of participants can be followed over time, and those who have a mild TBI subsequently can be compared to those without, although the practicality of these will need further investigation.

The current study shows that a population-based study of such substantial size is feasible. Future studies can extend on findings from this study by exploring other classification systems of mild TBI to establish predictive value of such systems for mild TBI outcomes, as this study only looked at one classification system which was not predictive of PCS at six months. Given the literature on this subject, the usefulness of classifying mild remains open to debate, and hence is worth exploring further. Future studies can include healthy controls to account for natural changes and allow comparisons to the mild TBI group to further clarify and establish the extent of deficits caused by mild TBI. Additionally, an extra assessment at three months may be considered, given it has been reported extensively that most symptoms resolve within three months, this appears to be an important time point in terms of recover. Therefore, it would be useful to see the changes between three and six months post-injury. Other factors to consider which may not be as easily rectified in a prospective population based study include pre-injury measures for pre-morbid functioning, more comprehensive measures of functioning in all domains, and administering the GCS for all participants as soon as possible post-injury.

Conclusion

In conclusion, this study highlights the significant problem of mild TBI in NZ. Findings from this study suggests that those at risk include Māori, the young and the elderly, who are several times more likely to experience a mild TBI than the rest of the population. However, as discussed above, caution should be made in generalising this finding given small population base numbers particularly for the elder age bands. These have implications for planning and implementing preventative strategies and rehabilitative needs. This study also confirms that despite the term "mild", a number of deficits in various domains of functioning are present up to six months post-injury, and that these deficits are not so "subtle". In terms of the development of PCS, those at risk include females, those who report poorer GOS outcomes, worse social, and neuropsychological functioning at baseline. Another aim of this study was to examine the accuracy of Servadei, et al.'s (2001) high versus low risk mild TBI categories in predicting who will develop PCS. Although this classification system was not found to be predictive of PCS outcomes, it was linked to performance in the areas of emotional and cognitive functioning, indicating it is potentially useful.

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APPENDICES

Appendix A: Participant Information Sheet and Consent Form

Adult Participant Information Sheet

An invitation

You are invited to take part in a research study because you have recently had a head injury (brain injury). This study is coordinated by the National Research Centre for Head injury, Applied Neurosciences and Neurorehabilitation, AUT University in Auckland in collaboration with Waikato University in Hamilton.

Your participation is entirely voluntary (your choice). You do not have to take part in this study. If you choose not to take part, any care or treatment that you are currently receiving will not be affected. If you do agree to take part, you are free to withdraw from the study at any time, without having to give a reason. Withdrawing at any time will in no way affect your future health care. To help you make your decision please read this information brochure. You may take as much time as you like to consider whether or not to take part. If you require an interpreter this may be arranged.

What are the aims of this study?

The main aim of the study is to determine the broad impact of head injury in New Zealand. We will be looking at the frequency, characteristics and effects on all people who suffer a new head injury who live in Hamilton and Waikato District over a 12 month period, from March 2010 to February 2011.

The study also aims to find out what the effects of the head injury (if any) are on:

- Physical activity
- Memory and other cognitive functioning
- Mood and feelings
- Quality of life
- The families of people with TBI

We hope this study will be of long-term benefit to New Zealanders in identifying incidence, mechanisms and outcomes of TBI, and eventually lead to an improved care and reduction in the number of TBI patients in New Zealand.

What types of people can be in the study?

All people who are resident in Hamilton or Waikato District who suffer a head injury between 1 March 2010 to 28 February 2011 are able to participate in the study.

We would also like to ask a family member or carer of people who have had a brain injury, so that we can ask them some questions about how your injury may have affected them. We will ask you if you would like to nominate someone to answer these questions

How many people will be in the study?

We estimate about 1040 people will be involved in this study.

What happens if I do decide to take part?

Participant's medical records will be checked to identify participants eligible for the study and to find out information about the type and nature of their injury. If you decide you would like to take part, your participation would be for twelve months only. In total there will be four assessments. These assessments will take place at the start of the study and then at 1 month and 6 months and 12 months after your head injury.

Each assessment will include answering some questions about your injury. This will take about 60 minutes and can be conducted over the telephone or in person. All researchers who will be asking you some questions will have been specifically trained for this project. You will be asked questions about your recovery, mood, treatments, care and services that you have received after the onset of your head injury.

The researcher will then arrange a suitable time to visit you at home. You will also be asked to complete some activities on a computer (the computer will be provided for you). These activities will look at your attention span, memory and the way you process information. This will help us to see if your injury may have affected your skills and to monitor your recovery. The computer activities will last for 60 minutes and there will be opportunities for you to take a break. These activities can also be done over several sessions if you prefer. In previous studies people have often said that they find these activities enjoyable.

In total the four study interviews should take about 8 hours of your time over twelve months.

What is the time-span for the study?

The study is expected to start on 1 March 2010 and will continue until 30 October 2012.

How will the study affect me?

Taking part in this study will take some of your time and require you to answer a series of questions. There are no known risks caused by this study. Your usual medical care will not be affected in any way by participating in the study, or by declining to participate or withdrawing from the study at any stage. Your participation in this study will be stopped should any harmful effects appear or if the doctor feels it is not in your best interests to continue. Similarly your doctor may at any time provide you with any other treatment he/she considers necessary.

This study will be of benefit to the wider population. There is no guarantee that you will benefit directly from being involved in this study. However, you will be given an opportunity to discuss your injury with someone who is an expert in head injury. The results obtained from your participation may help others with this condition in the future.

Compensation

A $20 food/fuel voucher will provided to you after completion of Interviews 2,3 and 4 ($60 in total).

If someone involved in the study experiences a further head injury during the study, they will be asked to continue with the scheduled follow up assessments for their initial injury as planned. Participants will only be eligible for these vouchers for one head injury occurring between 1 March 2010 to 28 February 2011, not including previous or further injury.

Confidentiality

The study files and all other information that you provide will remain strictly confidential. No material that could personally identify you will be used in any reports on this study. Upon completion of the study your records will be stored for 16 years in a secure place at the central coordinating centre in Auckland. All computer records will be password protected. All future use of the information collected will be strictly controlled in accordance with the Privacy Act.

Your Rights

If you have any queries or concerns about your rights as a participant in this study, you may wish to contact a Health and Disability Advocate at the Health Advocates Trust,

Telephone **0800 555 050**, or email: advocacy@hdc.org.nz

Or Te Puna Oranga (Waikato DHB Māori Health Unit), Hockin Building, Level 1, Pembroke St, P.O.Box 934, Hamilton. Ph: (07) 834 3644. Fax: (07) 834 3619.

Finally

This study has received Ethical Approval from the Northern Region Y Ethics Committee 19th October, 2009.

If you would like some more information about the study please feel free to contact the BIONIC Study Manager:

Study Manager on 0508 BIONIC (0508 246642) or email bionic@aut.ac.nz
Waikato University and National Research Centre for Stroke, Applied Neurosciences and Neurorehabilitation (NRC-SANN), AUT University

Alternatively, you can contact;
Dr Nicola Starkey, Senior Lecturer, Department of Psychology, University of Waikato, Hamilton, on 07 8384466 ext 6472 or email: nstarkey@waikato.ac.nz or Ms Alice Theadom, Senior Research Fellow, NRC-SANN, AUT University on 09-921-9999 ext. 7805 or email: alice.theadom@aut.ac.nz

Study Investigators

The principal investigator for this study is: **Professor Valery Feigin** Tel: (09) 921 9166
National Research Centre for Stroke, Applied Neurosciences and Neurorehabilitation (NRC-SANN), AUT University, Private Bag 92006, Auckland 1142

Please keep this brochure for your information.
Thank you for reading about this study

CONSENT FORM

	REQUEST FOR INTERPRETER		
English	I wish to have an interpreter.	Yes	No
Māori	E hiahia ana ahau ki tetahi kaiwhakaMāori/kaiwhaka pakeha korero.	Ae	Kao
Samoan	Oute mana'o ia iai se fa'amatala upu.	Ioe	Leai
Tongan	Oku ou fiema'u ha fakatonulea.	Io	Ikai
Cook Island	Ka inangaro au i tetai tangata uri reo.	Ae	Kare
Niuean	Fia manako au ke fakaaoga e taha tagata fakahokohoko kupu.	E	Nakai

1. I have read/had explained to me, and understand, the Information Sheet (Version6, dated 17/07/2009) for adult participants taking part in the BIONIC study. I have had the opportunity to discuss this study. I am satisfied with the answers I have been given.

2. I understand that taking part in this study is voluntary (my choice). I realise the study involves an interview with medical and lifestyle questions, that I may choose not to answer any questions or withdraw from the study at any time and this will in no way affect my future health care.

3. I have had the opportunity to use family/whānau support or a friend to help me ask
4. questions and understand the study.

5. I agree to an approved auditor appointed by either the ethics committee, or the regulatory authority or their approved representative, and approved by the Northern Region Y Ethics Committee reviewing my relevant medical records for the sole purpose of checking the accuracy of the information recorded for the study.

6. I give my approval for information regarding my present illness to be obtained from medical records.

7. I understand that my participation in this study is confidential and that no material that could identify me will be used in any reports on this study.

8. I understand the compensation provisions for this study.

9. I have had time to consider whether to take part.

10. I know whom to contact if I have any questions about the study.

11. I understand that my GP will be contacted about my participation in this study.

I am indicating my approval (or otherwise) for the following:

I wish to receive a copy of the results. I understand that there may be a significant delay between data collection and the publication of the study results. Yes / No

I _____ hereby consent to take part in this research.

OR

I am a representative of _____ (the participant), being a person who is lawfully acting on the participant's behalf or in his or her interests. My relationship to the participant is_____. I agree to health information about the participant being disclosed for the purposes of this research. I also agree to participate in this research.
(Please draw a line through the statement above that is not relevant).

Signature
(or representative)..... Signature of witness…….

Date: ..... Name of witness……...

Project explained by..... Project role ……

Signature..... Date ……

Note: A copy of the consent form to be retained by participant and a copy to be placed in the Case Record File

Approved by the Northern Region Y Ethics Committee

Appendix B: Case Ascertainment Form

FORM A: Case Notification

(For ALL Participants)

Information to be obtained from medical notes and/or interview
(To be collected at 1 month if not available at baseline)

1.1	Date of Birth	
1.2	NIH Number	
1.3	Date and time of Injury	
1.4	Date of first presentation of injury	
1.5	Date of participant identification	
1.4	Gender	Male/Female
1.6	Inclusion criteria;	Yes/No
	Resident of Hamilton	Yes/No
	Resident of Waikato District	Yes/No
	TBI between 1 March 2010 and 28 Feb 2011	(If answer no to the above, the person is not eligible for the study)
1.7	Ethnicity (tick **as many as apply**)	New Zealand European
		Māori
		Samoan
		Cook Island Māori
		Tongan
		Niuean
		Chinese
		Indian
		Other (such as Dutch, Japanese, Tokelauan)
1.8	If Other, specify	
1.9	How was this case located?	Waikato Hospital
		Auckland Hospital
		Middlemore Hospital
		Other hospital (specify)
		GP (general Practitioner)

		Accident and Medical Clinic (place)
		Private Hospital, Rest Home
		Concussion Clinic (place)
		Participant self-referral
		Coroner, Death Certificate
		ACC database
		Sports or recreational club
		Cavit ABI Rehabilitation
		Other, eg. Rehabilitation service, Brain Injury Association
1.10	Location of participant at time of notification	At home at time of notification
		In hospital or other institution at time of notification
		Deceased

2.0. TBI Severity

2.1	Glasgow Coma Scale at Scene	
2.2	If no GCS at scene, why not	Dead at scene
		Mild TBI only
		Other
2.3	Glasgow Coma Scale at admission?	
2.3.1	Worst GCS Scale recorded	
2.4	If no GCS at admission, why not?	Never Admitted
		Dead on Arrival
2.5	Length of Loss of Consciousness	
	(in hours; if no LOC = 0)	

2.6	Participant still in Posttraumatic Amnesia?	Yes/No
2.7	If No, length of PTA in days	
2.8	Severity rating	Mild
		Moderate
		Severe
2.9	If Mild	Low risk
		Medium risk

TBI severity definition for Assessors

GCS	GCS	PTA (Westmead PTA Scale)	Loss of Consciousness	Clinical Findings§	Neurological deficits	Skull Fracture	Risk Factors*
Severe	8 or less	> 1 day	> 24 hours				
Moderate	9 to 13	30 mins to 24 hours	1 to 24 hours				
Mild	14 or 15	< 1 hour	< 30 minutes				
Low Risk	15	< 1 hour	< 30 minutes	Absent	Absent	Absent	Absent
Medium Risk	15	< 1 hour	< 30 minutes	Present	Absent	Absent	Absent
High Risk	14	< 1 hour	< 30 minutes	May or may not be associated with clinical or radiological findings			
High Risk	15	< 1 hour	< 30 minutes				
High Risk	15	< 1 hour	< 30 minutes				
High Risk	15	< 1 hour	< 30 minutes				

§Clinical Findings= one or more of: Loss of consciousness, amnesia, vomiting, diffuse headache
*Risk factors = coagulopathy, drug/alcohol consumption, previous neurosurgical procedures, pre-trauma epilepsy, age over 60 years

3.0 Coma and Seizures

3.1	Did participant enter coma?	Yes/No
3.2	If yes, was the coma induced?	Yes/No
3.3	If Yes, length of coma in days.	
3.4	Did the participant have fits or seizure after their brain injury?	Yes/No
3.5	Is the participant still in a coma?	Yes/No
3.6	Is the participant capable of participating in the assessment?	Yes/No
3.6.1	If no, please state reason	In a coma Post traumatic amnesia Significant communication difficulties Other specify_____

4.0 Brain Injury Characteristics (as determined by CT/MRI/surgery or autopsy; a copy of the CT/MRI/surgery or autopsy findings should be attached)

4.1	Hemisphere of lesion	Left Right Both No evidence
4.2	Lobe of lesion(tick as many as applies)	Frontal Temporal Parietal Occipital No evidence
4.3	Skull Fracture	Yes/No
4.3.1	If yes, which hemisphere?	Left Right Both No evidence
4.3.2	If yes, which lobe (s) (tick as many as apply)	Frontal Temporal Parietal Occipital No evidence
	Evidence of;	
4.4	External lacerations	Yes/No
4.5	Bruising	Yes/No
4.6	Subdural haematoma	Yes/No
4.7	Epidural haematoma	Yes/No
4.8	Subarachnoid haemorrhage	Yes/No
4.9	Other identified structural lesion	Yes/No
4.9.1	If Yes, specify	

5.0 Other injuries sustained and acute interventions

5.1	Time of injury	
5.2	Is there a record of a hospital or GP consultation immediately after the incident	Yes/No
5.2.1	If yes, what was the outcome of the consultation?	Discharged and sent home Onward referral Hospitalised for injury Patient left against advice Other please specify_____
5.3	Was the TBI mentioned in the diagnostic codes on the medical record?	**Yes,** as a primary diagnosis **Yes,** as a secondary diagnosis **Not mentioned** in the diagnosis fields, but mentioned in other parts of medical record **Not mentioned at all**
5.4	Did the participant sustain any additional injuries?	Yes/No
	If yes, describe	
5.4.1	Which of the following did they receive?	
5.4.2	Neurosurgery	
5.4.3	Orthopaedic surgery	
5.4.4	Other surgery	
5.5	Was the ACC claim launched?	Yes/No
5.5.1	If yes, date	
5.5.2	If yes, claim number	
5.6	Did they require a breathing tube?	Yes/No
5.6.1	If yes, for how long? (days)	

5.7	Did they require a feeding tube?	Yes/No
5.7.1	If yes, for how long? (days)	
5.8	Did they have increased pressure on the brain that required monitoring?	Yes/No
5.8.1	If yes, for how long? (days)	

6.0 Diagnostic Tests

6.1	Angio	Yes/No
6.2	CT scan	Yes/No
6.3	Skull X-ray	Yes/No
6.4	EEG	Yes/No
6.5	Transcranial Doppler	Yes/No
6.6	MRI	Yes/No
6.7	MRA	Yes/No

Study Researcher to complete

Signature

Printed name

Date

Once this form is complete, send to the BIONIC Study Manager. Please obtain signed informed consent and complete Form C (Contact Details).

Appendix C: Baseline only measures

Information collected at baseline assessment only

Form B1: Baseline
Adults (aged 16 +)

1.0 General Questions

1.1	Assessment:	Baseline 1 month 6 months 12 months
1.2	Date of Assessment	
1.3	Participant is alive on scheduled assessment date	Yes/No/Unknown
1.3.1	If unknown, Date last definitely known to be alive (Stop here, YYYY must be 2010, 2011)	
1.3.2	If No, Date of Death (Ensure death is reported on Form D, Stop here, YYYY must be 2010, 2011)	
1.4.0	Is further data be obtained from client this scheduled assessment	Yes/No
1.4.1	If No, reason for missed assessment (Stop here, date, sign and send form. Go to Proxy form if Consent of Proxy Obtained)	0. refuses 1. participant aged < 2.0 years 2. cannot be contacted 3. overseas 4. too unwell 5. other specify _____
1.4.2	If No, is data to be collected from a proxy?	Yes/No
1.5	Has participant entered permanent residential care?	Yes/No
1.5.1	If yes, Date of entry into permanent residential care	
1.6	Has participant been admitted to hospital?	Yes/No
1.6.1	If yes, Date last admitted to hospital	
1.7	Has the participant had a serious fall?	Yes/No

1.7.1	If yes, Date of fall/injury	
1.8	Has the participant had a subsequent brain injury	Yes/No
	If yes please complete another form A	

1.9	Is English your first language?	Yes/No.
1.9.1	If no, do you need an interpreter?	Yes/No
1.9.2	If Yes, what language?	
1.10	Have you completed a Consent Form(s)?	Yes/No
1.10.1	Which Consent form was completed	Adult Participant Adult Proxy Both
1.11	Have you completed a Form C (Contact Details)	Yes/No
1.12	Is there a family member with whom you live that we could contact about their experience of your injury? If you need support with daily activities this may be the person who helps you the most.	Yes/No
1.12.1	If Yes, what are their contact details?	
1.13	What was your work situation before your injury? (tick one circle only)	Full time paid work Part time paid work Retired Unemployed or redundant Beneficiary Homemaker Student Other
1.13.1	If employed, what was your occupation?	

1.13.2	If Other, please specify:		
1.14	What is the highest level of education that you attained?	Primary School High School Polytechnic University	
1.16	In the last four weeks before the TBI event were you dependent on anyone for help with everyday activities (eg. Dressing, showering)?	Yes/No	
1.16.1	What is the main reason you need help? (tick one only)	previous head injury other health condition (specify)	

2.0 Injury Mechanism

2.1	Place: Where was the subject when he/she was injured?	Private house/compound School Highway/Road/Street Recreational area Work Other (specify) Unknown
2.2	Activity: What was the subject doing when he/she was injured?	Work Leisure/Play Sport Travelling In a conflict situation Other (specify) Unknown
2.3	What is the mechanism of injury?	Traffic Fall Industrial Recreational Assault Other
2.3.1	If 3.2= MVA, what type?	1= Car vs Car 2= Car vs Motorcycle/scooter 3= Car vs bicycle 4= Car vs Pedestrian 5 = Car vs other object

		6 = Bicycle
	If 3.2.1 = 2, was participant on the Motorcycle/scooter?	Yes/No
	If 3.2.1 = 3, was participant on the bicycle?	Yes/No
	If 3.2.1 = 4, was participant the pedestrian?	Yes/No
	If 3.2.1 = 5, specify – what was the other object?	Text
	If 3.2.1 = 6, what did the bicycle hit?	Text
	If 3.2 =MVA, was speed a factor?	Yes/No
	If 3.2= MVA, was talking on the phone or text messaging a factor?	Yes/No
	If 3.2 = MVA, was driver fatigue a factor?	Yes/No
2.3.2	If 3.2= Fall, where was the place you fell?	At home, indoors (including rest home, hospital) At home, outdoors (garden, playground) Away from home
If 3.2= Fall, did this fall result in a fracture?		Yes/No
If Yes, what did you fracture?		
2.3.3	If 3.2= other, specify	
2.4	Intent	Unintentional (accidental) Intentional (self-harm) Intentional (assault/violence) Undetermined Unknown
2.5	Regardless of mechanism, was alcohol involved / implicated?	Yes, suspected by report or confirmation No

		Unknown
2.6	Did the subject use alcohol 6 hrs before the incident?	Yes, suspected by report or confirmation No Unknown
2.7	Any evidence of alcohol use in this incident (other than the patient)?	Yes, suspected by report or confirmation No Unknown
2.8	Were drugs involved/ implicated?	Yes, suspected by report or confirmation No Unknown
2.9	Did the subject use marijuana or any other mood-altering substance 6 hrs before the incidence?	Yes, suspected by report or confirmation No Unknown
2.10	Any evidence of marijuana or any other mood-altering substance use in this incident (other than the patient)?	Yes, suspected by report or confirmation No Unknown
2.11	Is this your first TBI episode?	First Second Third Unknown

3.0 Pre-morbid conditions

Now I am going to ask you about any medical conditions. Has a doctor or medical person ever told you that you have any of the following:

3.1	Previous Head Injury (resulting in loss of consciousness)	Present Not present
3.2	Concussion	Present Not present
3.16	Any psychiatric illness (such as depression, anxiety disorder, schizophrenia, paranoia)	Present Not present
3.16.1	If yes, specify	Depression Anxiety disorder PTSD Schizophrenia Obsessive Compulsive Disorder Other
3.16.2	If Other, Specify	

4.0 Living arrangements (of Participant)

4.1	What is your current marital status? (tick one circle only)	Married, civil union, de facto Separated/divorced/widowed Never married (single) Unknown
4.2	Do you live alone? (tick one circle only)	Yes/No
4.2.1	If No, Living with family	Yes/No
4.2.2	If No, Living with partner	Yes/No
4.2.3	If No, Living with others	Yes/No

4.3	What is your usual dwelling place? (tick one circle only)	Inpatient or rest home Rented accommodation Own or family home Other
4.3.1	If Other, please specify:	
4.4	Has your home (or current dwelling place) had aids, appliances or modifications to allow you to live there since your TBI?	Yes/No
	If Yes, which of the following: (tick one circle only on each line)	
4.4.1	Communication aids	Yes/No
4.4.2	Commode chair	Yes/No
4.4.3	Rails in bedroom	Yes/No
4.4.4	Rails in bathroom	Yes/No
4.4.5	Walking stick or other aid	Yes/No
4.4.6	Ramps	Yes/No
4.4.7	Communication aids	Yes/No
4.4.8	If Other, please specify:	
4.5	Have you returned to your pre-injury job?	Yes/No
4.5.1	If yes, how many hours per week do you work?	Full time (35+ hours per week 20-34 hours per week <20 hours per week
4.5.2	Have you changed jobs since your injury? please specify:	
4.5.3	If you have changed jobs since your injury how many hours do you work per week?	35+ per week 20-34 hours per week <20 hours

4.5.4	If you have changed jobs since your injury what is your new occupation?	
4.6.1	Are you the main income earner in the family/household?	Yes/No
4.6.1	If No, what is (was) the main lifetime occupation of the main income earner?	
4.7	Thinking of your money situation right now, would you say: (tick one circle only)	I cannot make ends meet I have just enough to get along I am comfortable Decline to answer Don't know
4.8	Since your head injury has your income remained	About the same About 80% About 50% Less than 30%
4.9	Since your head injury, do you require unpaid help from another person for everyday activities (e.g. dressing, shopping, showering)?	Yes/No
4.10	If Yes, who is the person who helps you the most but who is not paid to do so?	Spouse/partner parent child sibling other relative neighbour friend other

5.0 Risk Factors

5.1	Which of these best describes your smoking status? (tick one circle only)	Never smoked Ex-smoker; smoked (cigarettes, ready made or roll your own; cigars, cigarillos or pipe) more than once per day for at least one year) Current smoker; currently (smokes cigarettes, ready made or roll your own, cigars, cigarillos or pipe) more than once per day for at least one year)
5.2	Did you regularly drink any type of alcohol prior to your injury?	Yes/No
5.3	If No, Did you **ever** drink alcohol regularly (at least once a month)?	Yes/No
5.4	If Yes, Which of the following best describes how often (tick one circle only)	Four or more times a day Two or three times a day Once a day Every 2 days Every 3 or 4 days Every 5 or 6 days Once a week Every 10 days Once a fortnight Once a month
5.5	Average number of standard units of alcohol consumed on each occasion (a standard drink is a small can of beer (330 ml), a small glass of wine or a single measure of spirits, equivalent to 10g of alcohol)	

Appendix D: RAND 36-Item Health Survey (SF-36; Ware, et al., 1994)

Medical Study Short Form (SF-36) (Australia/New Zealand, Version 1.0)

This questionnaire asks for your views about your health, how you feel and how well you are able to do your usual activities.

Answer every question by marking the answer as indicated. If you are unsure about how to answer a question, please give the best answer you can.

11.1	In general, would you say your health is:	1. Excellent 2. Very good 3. Good 4. Fair 5. Poor
11.2	Compared to one year ago, how would you rate your health in general now?	1. Much better now than one year ago 2. Somewhat better now than one year ago 3. About the same as one year ago 4. Somewhat worse now than one year ago

11.3 The following questions are about activities you might do during a typical day. Does your health now limit you in these activities? If so, how much? (circle one number on each line)

		Yes, limited a lot	Yes, limited a little	No, not limited at all
11.3.1	**Vigorous activities**, such as running, lifting heavy objects, participating in strenuous sports	1	2	3
11.3.2	**Moderate activities**, such as moving a table, pushing a vacuum cleaner, bowling, or playing golf	1	2	3
11.3.3	Lifting or carrying groceries	1	2	3
11.3.4	Climbing **several** flights of stairs	1	2	3
11.3.5	Climbing **one** flight of stairs	1	2	3

11.3.6	Bending, kneeling or stooping	1	2	3
11.3.7	Walking **more than one kilometre**	1	2	3
11.3.8	Walking **half a kilometre**	1	2	3
11.3.9	Walking **100 metres**	1	2	3
11.3.10	Bathing or dressing yourself	1	2	3

11.4 During the past 4 weeks, have you had any of the following problems with your work or other regular daily activities as a result of your physical health? circle one number on each line)

		Yes	No
11.4.1	Cut down on the **amount of time** you spent on work or other activities	1	2
11.4.2	**Accomplished less** than you would like	1	2
11.4.3	Were limited in the **kind** of work or other activities	1	2
11.4.4	Had **difficulty** performing the work or other activities (for example, it took extra effort)	1	2

11.5 During the past 4 weeks, have you had any of the following problems with your work or other regular daily activities as a result of any emotional problems (such as feeling depressed or anxious)? circle one number on each line)

		Yes	No
11.5.1	Cut down on the **amount of time** you spent on work or other activities	1	2
11.5.2	**Accomplished less** than you would like	1	2

11.6	During the past 4 weeks, to what extent has your physical health or emotional problems interfered with	1. Not at all

	your normal social activities with family, friends, neighbours, or groups?	2. Slightly 3. Moderately 4. Quite a bit 5. Extremely
11.7	How much bodily pain have you had during the past 4 weeks?	1. No bodily pain 2. Very mild 3. Mild 4. Moderate 5. Severe 6. Very severe
11.8	During the past 4 weeks, how much did pain interfere with your normal work (including both work outside the home and housework)?	1. Not at all 2. A little bit 3. Moderately 4. Quite a bit 5. Extremely

11.9 These questions are about how you feel and how things have been with you during the past 4 weeks.

For each question, please give the one answer that comes closest to the way you have been feeling. How much of the time during the past 4 weeks - (circle one number on each line)

		All of the time	Most of the time	A good bit of the time	Some of the time	A little of the time	None of the time
11.9.1	Did you feel full of life?	1	2	3	4	5	6
11.9.2	Have you been a very nervous person	1	2	3	4	5	6
11.9.3	Have you felt so down in the dumps that nothing could cheer you up?	1	2	3	4	5	6
11.9.4	Have you felt calm and peaceful?	1	2	3	4	5	6
11.9.5	Did you have a lot of energy?	1	2	3	4	5	6
11.9.6	Have you felt down?	1	2	3	4	5	6
11.9.7	Did you feel worn out?	1	2	3	4	5	6
11.9.8	Have you been a happy person?	1	2	3	4	5	6
11.9.9	Did you feel tired?	1	2	3	4	5	6

11.10	During the past 4 weeks, how much of the time has your physical health or emotional problems interfered with your social activities (like visiting with friends, relatives, etc.)? (circle one)	1. All of the time 2. Most of the time 3. Some of the time 4. A little of the time

		5. None of the time

11.11 How TRUE or FALSE is each of the following statements for you? (circle one number on each line)

		Definitely True	Mostly True	Don't Know	Mostly False	Definitely False
11.11.1	I seem to get sick a little easier than other people	1	2	3	4	5
11.11.2	I am as healthy as anybody I know	1	2	3	4	5
11.11.3	I expect my health to get worse	1	2	3	4	5
11.11.4	My health is excellent	1	2	3	4	5

Appendix E: Glasgow Outcome Score (GOS; Jennett & Bond, 1975)

Glasgow Outcome Score

1 **(Good Recovery)** Capacity to resume normal occupational and social activities, although there may be minor physical or mental deficits or symptoms.

2 (**Moderate Disability)** Independent and can resume almost all activities of daily living. Disabled to the extent that they cannot participate in a variety of social and work activities.

3 (**Severe Disability)** No longer capable of engaging in most previous personal, social or work activities. Limited communication skills and have abnormal behavioral or emotional responses. Typically are partially or totally dependent on assistance from others in daily living.

4 (**Persistent Vegetative State)** Not aware of surroundings or purposely responsive to stimuli.

5 (**Dead)**

1=Good Recovery

2= Moderate Disability

3= Severe Disability

4 = Persistent Vegetative State

5 = Dead

Appendix F: Duke-UNC Functional Social Support Questionnaire (FSSQ; Broadhead, et al., 1988)

Duke-UNC Functional Social Support Questionnaire (SSQB)

Now I'm going to ask you about some things that other people might do for you or give you that may be helpful or supportive. As I read each statement, please tell me which answer is closest to your situation.
Here is an example:

	As much as I would like				Much less than I would like
I get enough free time	5	4	3	2	1

If you answer"4", it means that you get almost as much free time as you would like, but not quite as much as you would like. Answer each item as best you can. Remember, there are no right or wrong answers

	I get...	As much as I would like				Much less than I would like
11.1	Love and affection	5	4	3	2	1
11.2	Chances to talk to someone I trust about my personal and family problems	5	4	3	2	1
11.3	Invitations to go out and do things with other people	5	4	3	2	1
11.4	People who care what happens to me	5	4	3	2	1
11.5	Chances to talk about money matters	5	4	3	2	1
11.6	Useful advice about	5	4	3	2	1

	important things in life					
11.7	Help when I need transportation	5	4	3	2	1
11.8	Help when I'm sick in bed	5	4	3	2	1
11.9	Help with cooking and housework	5	4	3	2	1
11.10	Help taking care of my children	5	4	3	2	1

Appendix G: Community Integration Questionnaire (CIQ; Willer, Rosenthal, et al., 1993)

13.0 Community Integration Questionnaire (CIQ)

	Before your injury…	
13.1	Who usually did the shopping for groceries or other necessities in your household?	2 – Yourself alone 1-Yourself and someone else 0 – someone else
13.2	Who usually prepared meals in your household?	2 – Yourself alone 1-Yourself and someone else 0 – someone else
13.3	In your home who usually did normal everyday housework?	2 – Yourself alone 1-Yourself and someone else 0 – someone else
13.4	Who usually cared for the children in your home?	2 – Yourself alone 1-Yourself and someone else 0 – someone else *- Not applicable. Score is average of items 1, 2, 3, and 5
13.5	Who usually planned social arrangements such as get-togethers with family and friends?	2 – Yourself alone 1-Yourself and someone else 0 – someone else
13.6	Who usually looked after your personal finances, such as banking or paying bills?	2 – Yourself alone 1-Yourself and someone else 0 – someone else
13.7	Can you tell me approximately how many times a month you used to participate in shopping outside your home	2 – five or more times 1 - one to 4 times 0 - never

13.8	Can you tell me approximately how many times a month you used to participate in leisure activities such as movies, sports, restaurants, etc. outside your home	2 – five or more times 1 - one to 4 times 0 - never
13.9	Can you tell me approximately how many times a month you would usually participate visiting friends or relatives outside your home	2 – five or more times 1 - one to 4 times 0 - never
13.10	When you participated in leisure activities did you usually do this alone or with others?	0 – mostly alone 1 – mostly with friends who have head injuries 1 – mostly with family members 2 - mostly with friends who do not have head injuries 2 - with a combination of family and friends
13.11	Do you have a best friend with whom you confide?	2 – yes 0 - no
13.12	How often did you travel outside the home?	2 - almost every day 1 - almost every week 0 - seldom/never (less than once per week)
13.13	Please check the answer below that best corresponds to your (during the past month) work situation before your injury	full-time (more than 20 hours per week) part-time (less than or equal to 20 hours per week) not working, but actively looking for work not working, not looking for work not applicable, retired due to age

13.14	Please check the answer that best corresponds to your (during the past month) school or training program situation.	Full time Part time Not attending school/training not applicable, retired due to age
13.15	Before your injury, how often did you engage in volunteer activities?	5 or more times 1 to 4 times Never
13.16	HOME INTEGRATION SCORE = (sum of items 1 through 5)	
13.17	SOCIAL INTEGRATION SCORE = (sum of items 6 through 11)	
13.18	Job/School Integration Score (Items 13 through 15)	0 - Not working, not looking for work, not going to school, no volunteer activities. If retired, no activities per month 1 - Volunteers 1 to 4 times a month AND not working, not looking for work, not in school 2 - Actively looking for work AND/OR volunteers 5 or more times per month. If retired, 1 to 4 volunteer activities per month 3 - Attends school part-time OR working part-time (less than 20 hours per week) 4 - Attends school full-time OR works full-time. If retired, 5 or more volunteer activities per month 5- Works full-time AND attends school part-time; OR Attends school full-time AND works part-time (less than 20 hours per week)

13.19	PRODUCTIVITY SCORE = (sum of item 12 and the Jobschool variable)	2
13.20	TOTAL CIQ SCORE (range 0 to 29) = HOME INTEGRATION SCORE+SOCIAL INTEGRATION SCORE+PRODUCTIVITY SCORE	

Appendix H: Hospital Anxiety and Depression Scale (HADS; Zigmond & Snaith, 1983)

Hospital Anxiety and Depression Scale (HADS)

1. I feel tense or wound up

0- Not at all

1. From time to time, occasionally

2- A lot of the time

3- Most of the time

2. I get a sort of frightened feeling as if something awful is about to happen

0- Not at all

1- A little, but it doesn‟t worry me

2- Yes but not too badly

3- Very definitely and quite badly

3. Worrying thoughts go through my mind

0- Only occasionally

1- From time to time, but not too often

2- A lot of the time

3- A great deal of the time

4. I can sit at ease and feel relaxed*

0- Definitely

1- Usually

2- Not often

3- Not at all

5. I get a sort of frightened feeling like „butterflies‟ in the stomach

0- Not at all

1- Occasionally

2- Quite often

3- Very Often

6. I feel restless as if I have to be on the move

0- Not at all

1- Not very much

2- Quite a lot

3- Very much indeed

7. I get sudden feelings of panic

0- Not at all

1- Not very often

2- Quite often

3- Very Often

8. I still enjoy the things I used to enjoy*

0- Definitely as much

1- Not quite as much

2- Only a little

3- Hardly at all

9. I can laugh and see the funny side of things*

0- As much as I always could

1- Not quite so much now

2- Definitely not as much now

3- Not at all

10. I feel cheerful*

0- Most of the time

1- Sometimes

2- Not Often

3- Not at all

11. I feel as if I am slowed down

0- not at all

1- Sometimes

	2- Very often 3- Nearly all the time
12. I have lost interest in my appearance	0- I take just as much care as ever 1- I may not take quite as much care 2- I don‟t take as much care as I should 3- Definitely
13. I look forward with enjoyment to things*	0- As much as I ever did 1- Rather less than I used to 2- Definitely less than I used to 3- Hardly at all
14. I can enjoy a good book or TV programme*	0- Often 1- Sometimes 2- Not often 3- Very seldom

HADS-Anxiety score

[1 + 2 + 3 + 4(reversed) + 5 + 6 + 7]

HADS-Depression Score

[8 (reversed) + 9(reversed) + 10 (reversed) +11+ 12 + 13 (reversed) +14 (reversed)]

If participant scores <11 continue to question 13
If participant scores >11 complete DSM-IV assessment below and refer to GP

Appendix I: The Rivermead Post Concussion Symptoms Questionnaire (RPQ; King, et al., 1995)

Rivermead Post Concussion Symptoms Questionnaire (PCS)

After a head injury or accident some people experience symptoms that can cause worry or nuisance. We would like to know if you now suffer any of the symptoms given below. Because many of these symptoms occur normally, we would like you to compare yourself now with before the accident. For each symptom listed below please circle the number that most closely represents your answer.

Compared with before the accident, do you now (i.e., over the last 24 hours) suffer from:

	not experienced	no more of a problem	mild problem	moderate problem	severe problem
Headaches	0	1	2	3	4
Feelings of dizziness	0	1	2	3	4
Nausea and/or vomiting	0	1	2	3	4
Noise sensitivity (easily upset by loud noise)	0	1	2	3	4
Sleep disturbance	0	1	2	3	4
Fatigue, tiring more easily	0	1	2	3	4
Being irritable, easily angered	0	1	2	3	4
Feeling depressed or tearful	0	1	2	3	4
Feeling frustrated or impatient	0	1	2	3	4
Forgetfulness, poor memory	0	1	2	3	4
Poor concentration	0	1	2	3	4
Taking longer to think	0	1	2	3	4
Blurred vision	0	1	2	3	4

Light sensitivity (easily upset by bright light)	0	1	2	3	4
Double vision	0	1	2	3	4
Restlessness	0	1	2	3	4
Hemiplegia	0	1	2	3	4
Dysphasia	0	1	2	3	4
Difficulty swallowing	0	1	2	3	4
Sensory Deficits	0	1	2	3	4
Aggression	0	1	2	3	4
Balance difficulties	0	1	2	3	4
Difficulties with sexual functioning	0	1	2	3	4
Digestion	0	1	2	3	4
Difficulties with fine motor tasks (e.g. picking things up)	0	1	2	3	4
Are you experiencing any other difficulties? Please specify, and rate as above.					
1.	0	1	2	3	4
2.	0	1	2	3	4

Appendix J: Cognitive Failures Questionnaire (CFQ; Broadbent, et al., 1982; Wallace, 2004).

The Cognitive Failures Questionnaire (CFQ)

The following questions are about minor mistakes which everyone makes from time to time, but some of which happen more often than others. We want to know how often these things have happened since your injury. Please circle the appropriate number.

	Very often	Quite often	Occasionally	Very	rarely	Never
12.1	Do you read something and find you haven't been thinking about it and must read it again?	4	3	2	1	0
12.2	Do you find you forget why you went from one part of the house to the other?	4	3	2	1	0
12.3	Do you fail to notice signposts on the road?	4	3	2	1	0
12.4	Do you find you confuse right and left when giving directions?	4	3	2	1	0
12.5	Do you bump into people?	4	3	2	1	0
12.6	Do you find you forget whether you've turned off a light or a fire or locked the door?	4	3	2	1	0
12.7	Do you fail to listen to people's names when you are meeting them?	4	3	2	1	0
12.8	Do you say something and realize afterwards that it might be taken as insulting?	4	3	2	1	0

12.9	Do you fail to hear people speaking to you when you are doing something else?	4	3	2	1	0
12.10	Do you lose your temper and regret it?	4	3	2	1	0
12.11	Do you leave important letters unanswered for days?	4	3	2	1	0
12.12	Do you find you forget which way to turn on a road you know well but rarely use?	4	3	2	1	0
12.13	Do you fail to see what you want in a supermarket (although it's there)?	4	3	2	1	0
12.14	Do you find yourself suddenly wondering whether you've used a word correctly?	4	3	2	1	0
12.15	Do you have trouble making up your mind?	4	3	2	1	0
12.16	Do you find you forget appointments?	4	3	2	1	0
12.17	Do you forget where you put something like a newspaper or a book?	4	3	2	1	0
12.18	Do you find you accidentally throw away the thing you want and keep what you meant to throw away – as in the	4	3	2	1	0

	example of throwing away the matchbox and putting the used match in your pocket?					
12.19	Do you daydream when you ought to be listening to something?	4	3	2	1	0
12.20	Do you find you forget people‟s names?	4	3	2	1	0
12.21	Do you start doing one thing at home and get distracted into doing something else (unintentionally)?	4	3	2	1	0
12.22	Do you find you can't quite remember something although it's "on the tip of your tongue"?	4	3	2	1	0
12.23	Do you find you forget what you came to the shops to buy?	4	3	2	1	0
12.24	Do you drop things?	4	3	2	1	0
12.25	Do you find you can't think of anything to say?	4	3	2	1	0