Exploring Psychological Mechanisms that Contribute to the Development of Post-Traumatic Stress Disorder in Mild Traumatic Brain Injury

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Abstract

Mild traumatic brain injuries (mTBI) are prevalent. Contrary to previous beliefs, a significant portion of individuals experience persistent post-concussion symptoms. Psychological mechanisms have been found to increase pathologies such as post-traumatic stress disorder (PTSD) and affect functional status within a large spectrum of health disorders. Alas, they have not been vastly explored within an mTBI population. This study examined the role of psychological flexibility and fear avoidance in the development of PTSD post-mTBI. ***Method:*** 169 participants were recruited from a specialist concussion service and completed a range of self-report measures within one month of entry. The psychological mechanisms were ascertained. This included psychological flexibility (Acceptance and Action Questionnaire in Acquired Brain Injury (AAQ-ABI(RA)) and fear avoidance (Fear Avoidance Behaviour after Traumatic Brain Injury Questionnaire (FAB-TBI)). In addition, measures of, psychological distress (Depression Anxiety and Stress Scale, DASS-21), post-traumatic stress disorder symptoms (PTSS) (Impact of Events Scale-Revised (IES-R)), post-concussion symptoms (PCS) (Rivermead Post-Concussion Questionnaire, (RPQ)), and functional disability (Word Health Organisation Disability Assessment Schedule 2.0 WHODAS 2.0) were gathered. ***Results***: A large positive correlation was found between PTSS, PCS and functional disability. Linear regression analysis revealed that psychological flexibility and fear avoidance made a unique and significant contribution to PTSS in mTBI, even when controlling for confounding variables. Mediation analysis revealed an indirect effect of PTSS on PCS and functional status through both psychological mechanisms. Multiple mediation indicated that psychological flexibility was significantly associated with PCS, but fear avoidance was not. Whereas both were associated with functional status. ***Conclusion:*** PTSS significantly contribute to mTBI outcomes (i.e., PCS, functional status).

Psychological flexibility and fear avoidance contribute to the development of PTSS following mTBI and affect recovery. These findings suggest that psychological flexibility and fear avoidance should be targeted in treatment interventions for mTBI.

Keywords: Mild Traumatic Brain Injury, Post-Traumatic Stress Disorder, Post-Traumatic Stress Symptoms, Psychological Flexibility, Fear Avoidance, Outcomes, Post-Concussion Symptoms, Functional Status

Dedication

This thesis is dedicated to my daughter Skylara. I want you to know that anything is possible even when it seems unreachable. If you have a vision and goals and work hard enough you can accomplish and achieve anything you put your mind to. You have been on this journey with me since you were one and therefore, I dedicate this thesis to you on your ninth birthday. With all my love -Mum.

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Table of Contents

List of Figures

List of Tables

List of Abbreviations

mTBI	Mild Traumatic Brain Injury
TBI	Traumatic Brain Injury
bTBI	Blast-Induce TBI
PTSD	Post-Traumatic Stress Disorder
PTSS	Post-Traumatic Stress Disorder Symptoms
ASD	Acute Stress Disorder
PPCS	Persistent Post Concussion Symptoms
PCS	Post Concussion Symptoms
CDC	Centre for Disease Control
GCS	Glasgow Coma Scale
LOC	Loss of Consciousness
PTA	Post Traumatic Amnesia
AMS	Altered Mental States
ED	Emergency Department
ACRM	American Congress of Rehabilitation Medicine
APA	American Psychological Association
HPA	Hypothalamic-Pituitary-Adrenal Axis
GAD	Generalised Anxiety Disorder

OCD	Obsessive-Compulsive Disorder
DSM-V	Diagnostic and Statistical Manual of Mental Disorders
ICD-10	International Statistical Classification of Diseases and Related Health Problems
ACES	Early Adverse Childhood Events
IQ	Intelligence Quotient
FAM	Fear Avoidance Model
WHO	World Health Organisation
DASS-21	Depression, Anxiety Stress Scale
IES-R	Impact of Events Scale-Revised
AAQ-ABI (RA)	Acceptance and Action Questionnaire-Acquired Brain Injury (Reactive Avoidance (RA))
FAB-TBI	Fear Avoidance Behaviour after Traumatic Brain Injury Questionnaire
RPQ	Rivermead Post-Concussion Symptom Questionnaire
WHODAS 2.0	WHO Disability Assessment Schedule
HRQoL	Health-Related Quality of Life
CENTER-TBI	Collaborative European Neuro Trauma Effectiveness Research in Traumatic Brain Injury
CBT	Cognitive-Behavioural Therapy

ACT	Acceptance and Commitment Therapy
MTAU	Medical Treatment as Usual
LBP	Lower Back Pain
SI-PTSD	Structured Interview for PTSD
SCID	Structured Clinical Interview for *DSM-V*
CAPS-5	Clinician-Administered PTSD Scale for *DSM-5*
PC	Post-Concussed
HC	Healthy Control
TAU	Treatment as Usual

Chapter One: Introduction

The brain is a complex and fascinating organism. It weights three pounds (Schoenberg & Scott, 2011) and is a work of art. Each sulcus, gyrus, and lobe, functions independently and yet simultaneously to assert a form of action (Schoenberg & Scott, 2011). The brain functions as a pillar of intelligence, an interpreter of senses, a controller of thoughts and behaviour, an initiator of body movements and a developer of emotions (Schoenberg & Scott, 2011). This magnificent organ albeit so delicate, is the fountain of life which allows us to be who we are, helps us achieve what we desire, and yet can also imprison us. This can at times happen all at once or much like a roller coaster. Like our bodies, our brains too can sustain injuries. Although these injuries, such as forcible impacts to the head known as a mild traumatic brain injuries (mTBI), are invisible to the exterior, difficult to assess and manage, does not deter from the significant consequences they can produce. mTBI are known to be the most prevalent form of brain injuries which can create substantial long-term consequences (Johnson et al., 2015; Theadom et al., 2016; Pozzato et al., 2020; Konrad et al., 2011). These consequences implicate overall physical, emotional, psychological, and spiritual wellbeing, including functional ability in daily tasks (Konrad et al., 2011).

A high comorbidity with mTBI is a psychological disorder known as post-traumatic stress disorder (PTSD) (Stein et al., 2019; Combs et al., 2015). It is well recorded that sustaining an mTBI increases the risk of developing PTSD (Rickards et al., 2020; Polinder et al., 2018; Stein et al., 2019; Bryant, 2011; Bryant et al., 2010; Bryant, 2018; Zatzick et al., 2002; O'Donnell et al., 2004; Hoffman et al., 2012), for a number of reasons. Firstly, the nature in which the mTBI was suffered can be traumatic. Secondly, an individual’s predisposing factors including, childhood trauma, limited social support,

severity of the trauma and genetic predisposition can increase the risk of developing PTSD following a traumatic experience/event (Sadock et al., 2015). Thirdly, PTSD may develop due to a pathophysiological response from the mTBI (Lagardge et al., 2014). It is well documented that mTBI increase the risk of pathologies such as depression and anxiety (Dunlop & Wong, 2019; Patterson, 2016; Vanderploeg et al., 2009; Lagardge et al., 2014) including PTSD (Stein et al., 2019; Bryant et al., 2009; Bryant, 2011). Given these findings, the pathology of mTBI appears to be significant and should be taken into consideration. Lastly, pre-injury mental health has also been identified as a risk factor for the development of PTSD (Sadock et al., 2015; Sareen, 2014; Brewin et al., 2000) and mTBI (Rickards et al., 2020; Faulkner et al., 2020; Cassetta et al., 2021; Cnossen et al., 2018; Meares et al., 2008; Silverberg et al., 2015). It is evident that there are many etiological possibilities for the evolution of PTSD post-mTBI. More recently, research has focused on explaining this comorbidity using transdiagnostic models which identify psychological mechanisms that operate across disorders (Nolen-Hoeksema, & Watkins, 2011; Levin et al., 2014).

Psychological mechanisms such as psychological flexibility and fear avoidance have been found to either contribute or mitigate psychopathologies and adverse outcomes. For example, psychological inflexibility, the inability to adapt to changes in life increases the risk of mental health disorders including PTSD (Dutra & Sadeh; Bond et al., 2011; Masuda & Tully, 2012; Morris & Mansell, 2018). Previous research discovered that low levels of psychological flexibility was strongly associated with high levels of psychological distress and behavioural ineffectiveness including avoidance, rumination, and excessive worry (Bond et al., 2011). Psychological inflexibility has also been found to significantly impact mTBI recovery, increasing the risk of experiencing post-concussion symptoms (PCS) (Faulkner et al., 2020, 2021a) and affecting functional status (Levin et

al., 2014). In contrast, psychological flexibility has been found to mitigate PTSD (Dutra & Sadeh) and PCS (Faulkner et al., 2021a). Although much remains to be discovered, these findings highlight the important role psychological flexibility plays in contributing to recovery outcomes, and could therefore, be a potential treatment target in mTBI interventions.

Fear avoidance has also been identified as an important psychological mechanism in the contribution of maintaining and exacerbating PTSS (Sripada et al., 2013) and PCS (Wijenberg et al., 2017; Silverberg et al., 2018; Snell et al., 2020). Fear avoidance drives individuals to avoid certain activities, behaviours or locations due to a fear of experiencing pain, or other unwanted symptoms. Fear avoidance has been extensively examined among various health conditions such as chronic pain and is found to exacerbate symptoms and increase functional disability (Snell et al., 2020). Recently, research has been investigating fear avoidance among individuals with mTBI (e.g., Snell et al., 2020; Wijenberg et al., 2017). The results suggest that fear avoidance may predict poor prognosis post-mTBI increasing the risk of developing PCS and decreasing functional status (Wijenberg et al., 2017; Snell et al., 2020). This also proposes that treating fear avoidance mitigates negative outcomes for mTBI and thus, is a pivotal psychological mechanism to address.

A noteworthy gap in this literature has been found. Aside from limited data on the general population regarding mTBI and PTSD, the implications of PTSD symptoms (PTSS) on mTBI outcomes such as PCS and functional disability have rarely been addressed. Separately, both mTBI and PTSD have profound implications on all aspects of an individual's functioning, however, when combined exhibit tremendous long-term negative outcomes, cognitively and psychologically (Polusny et al., 2011). Given the significance of these negative outcomes, this research study will delve into better understanding the effects of PTSD on mTBI recovery, in addition to examining the

possible psychological mechanisms (psychological flexibility and fear avoidance) involved in the contribution and development of PTSD post-mTBI. Lastly, the current study will address whether psychological flexibility and fear avoidance mediate the relationship between PTSS, PCS and functional status separately and simultaneously to inform psychological interventions and guide rehabilitation strategies.

To begin with, chapter two will provide a literature review. This will start with relevant information regarding mTBI such as the prevalence rate, diagnostic criteria, symptomology, and pathophysiology. Furthermore, PCS will be discussed from a historical and current framework followed by re-examining the perceived belief that persistent post-concussion symptoms (PPCS) are not common. The prevalence rate and limitations will be identified regarding the non-specificity and general lack of consensus in defining PPCS. Furthermore, the etiology of PCS will be examined. For a more comprehensive understanding, the biopsychosocial model of PPCS will be discussed. PTSD will be the next topic of discussion, followed by the diagnostic criteria, symptomology, prevalence rate, etiology and lastly, models of PTSD. This section will be commenced by examining and providing explanations for how mTBI increases the risk of PTSD, while identifying the complications with ascertaining epidemiological data. The chapter will further provide a review of the influence PTSS have on mTBI recovery and describe the differences and similarities between these constructs. The last topic of the literature review will involve exploring psychological mechanisms and their contribution to PTSD, beginning with describing transdiagnostic boundaries which contribute to mental health. This will be followed by a summary discussing how these psychological mechanisms inform treatment and lastly, by introducing this studies research questions. Chapter three consists of the methodology which describes and justifies the procedure taken in this research endeavour. Chapter four includes the results section and introduces

the findings. Followed by chapter five, which discusses and evaluates the results and hypotheses. The discussion will also highlight the implications and limitations of the findings, followed by identifying areas for future research and ending with a conclusion in chapter six.

Chapter Two: Literature Review

1. Mild Traumatic Brain Injury

The Latin translation of concussion is to “shake violently” (Vagnozzi et al., 2010). When the head sustains a significant impact, or experiences high velocity movement, it can cause the brain to shake rapidly back and forth. This action can cause temporary physiological changes (Vagnozzi et al., 2010) affecting functioning (Schoenberg & Scott, 2011). Although the brain is encompassed by a protective suspension of cerebrospinal fluid within the skull (Schoenberg & Scott, 2011), a blow could nevertheless still cause stretching and damage to brain cells (Barker-Collo et al., 2015; Belanger et al., 2018). This is now, more commonly known as a mild traumatic brain injury (mTBI). mTBI are by far the most commonly occurring brain injuries, with 90% of all traumatic brain injuries (TBI) falling within the mild spectrum of the TBI scale (Lefevre-Dognin et al., 2021). mTBI are sustained through a myriad of factors such as accidents, combat/explosions, falls, sport injuries and violence (Schoenberg & Scott, 2011; Davis, 2014; Rickards et al., 2020; Belanger et al., 2018).

a. Prevalence

mTBI can impact people of all ages, races, cultures, and genders. Consequently, mTBI have become a significant public health problem in New Zealand and worldwide (Johnson et al., 2015; Theadom et al., 2016). The societal cost of mTBI in New Zealand is substantial (Te Ao et al., 2014). According to Te Ao et al. (2014) mTBI costed New Zealand, US $147 million in 2010 and was predicted to increase to US $177 million in 2020. According to the US Centre’s for Disease Control (CDC), approximately 42 million

people worldwide sustain a mTBI annually (Headway, 2021). In New Zealand, approximately 90 individuals sustain an mTBI injury everyday (Headway, 2021). Aside from sports injuries, accidents and assaults, falls appear to be the most common cause of mTBI (Pozzato et al., 2020). Therefore, the general population itself is at high risk (Blyth & Bazarian, 2010). Many mTBI are not reported due to the context within which they occur, such as domestic violence, assaults, or due to a lack of awareness regarding mTBI. Consequently, it is possible that the costs and prevalence rates are much higher than those informed. This form of under-reporting effects epidemiological data, thus impacting the allocation of adequate resources distributed, while also affecting information on evidence-based healthcare development (Pozzato et al., 2020). Individuals who do not seek treatment for mTBI often experience reduced functional ability, heightened emotional distress, and delayed return to work or school (Pozzato et al., 2020; Belanger et al., 2018). Studies have ascertained that early identification and subsequently early interventions (i.e., education and support) lead to a faster return of activities, significantly increasing social participation and decreasing the severity of post concussive symptoms (Pozzato et al., 2020). Evidently, the benefits of early interventions outweigh the risks of not being assessed. Although there is no clear indication of how prevalent mTBI is globally, it is apparent that it is a significant health problem affecting the general population. As such, research is needed to better understand the mechanisms of mTBI to provide appropriate and successful forms of treatment, thereby reducing the costs, and recovery processes.

b. Diagnostic Criteria and Symptom Presentation

mTBI are assessed using three primary criterions. These are: the Glasgow Coma Scale (GCS), loss of consciousness (LOC), and length of post traumatic amnesia (PTA). Firstly, GCS, a rapid screening instrument, evaluates the severity of the brain injury and

assesses the level of consciousness within three major categories, motor, verbal responses and eye-opening (Teasdale et al., 2014; Belanger et al., 2018; Craton & Leslie, 2013; Reith et al., 2016). Secondly, LOC is assessed. LOC usually lasts 30 minutes or less, although it is important to note that mTBI can occur in the absence of LOC (Kanefsky et al., 2019; Roitman et al., 2013). Thirdly, PTA can be defined by a temporary alteration in neurological functioning that occurs immediately following the injury, in which the person is disoriented and unable to remember events that occurred after impact (Schoenberg & Scott, 2011; Craton & Leslie, 2013; Hussain et al., 2019). Using these indicators, a mTBI is defined as loss of consciousness lasting no more than 30 minutes (if present), with an initial GCS score of 13 to 15, and posttraumatic amnesia (and/or other transient neurologic signs and symptoms) enduring for no longer than 24 hours (Kanefsky et al., 2019). Emergency departments (ED) are commonly the primary point of medical contact for early diagnosis for individuals with mTBI. However, accurate clinical identification of patients in ED is often challenging and complicated with these broad indicators (Pozzato et al., 2020). At present it is recognised that these tools used for assessing mTBI, lack sensitivity and as such multiple diagnostic criteria's for mTBI have been proposed (Pozzato et al., 2020).

For the purpose of this study, the American Congress of Rehabilitation Medicine (ACRM) diagnostic criteria for mTBI will be used (Lefevre-Dognin et al., 2021). Specifically, the ACRM defines mTBI as a traumatically induced physiological disruption of brain function manifested by one or more of the following: loss of consciousness (LOC) up to 30 minutes, loss of memory for events immediately before or after for up to 24 hours, and any alteration of mental status at the time of the accident that may or may not be traumatic (Lefevre-Dognin et al., 2021).

c. Pathophysiology

The pathophysiology of mTBI is complex and can be influenced by the mechanisms of the injury (Menon et al., 2010). There are three types of traumas to the head which cause temporary damage to the axons and stretching of the neurons while significantly changing the chemical makeup of the brain (Mychasiuk et al., 2016; Belanger et al., 2018). These traumas include coup, countercoup, and rotational forces. A coup injury directly injures the brain at the point of contact (Mychasiuk et al., 2016). For example, an individual whose head has impacted the steering wheel in a motor vehicle accident may sustain a coup injury to the frontal region of the brain. Secondly, a countercoup injury entails the brain being injured on the side opposite of the area that was hit (Mychasiuk et al., 2016). For example, an individual who experienced trauma from hitting their head on the steering wheel in a motor vehicle accident may sustain a countercoup injury to the occipital regions of the brain. These injuries can cause cerebral contusions which can be defined as bruising of the brain tissue (Mychasiuk et al., 2016). Lastly, mTBI can occur from rotational forces which may result in the shearing of axons (the cable transmissions of neurons), meaning the brains long connecting nerve fibres (axons) are torn (Schoenberg & Scott, 2011). A rotational brain injury is the result of a rapid change of the rotational velocity of the head. For example, this rapid change can be caused by a direct hit to the skull or by an indirect hit to the shoulder such as whiplash, leading to a rotational motion of the head. This type of injury is commonly experienced in motor vehicle accidents and with athletes (Mychasiuk et al., 2016).

When the brain sustains either of these injuries, normal brain function is temporarily disrupted. During this time, the brain sets off an influx of neurotransmitters such as glutamate (Laskowski et al., 2015). The release of these neurotransmitters causes the brain cells (neurons) to fire relentlessly, causing further disruptions to the chemical balance in neurons (Yasen et al., 2020). A chemical imbalance causes the neurons to send

electrical signals excessively (Laskowski et al., 2015). This extra work results in a greater demand for energy (Laskowski et al., 2015). However, the changes to the chemicals in the brain also impacts the cell's ability to break down oxygen, resulting in less energy (glucose) in the brain (Yasen et al., 2020). Blood vessels can also become restricted by the chemical changes in the brain, limiting the supply of new fuel (glucose) (Yasen et al., 2020). The high energy demand of neurons, versus the limited energy available, creates an energy crisis which exhausts the neurons, thus causing disruptions in neurological functioning (Laskowski et al., 2015). After a mTBI, the brain may require several days before the chemical imbalance is restored which constitutes full recovery (Laskowski et al., 2015). These pathophysiological changes result in the presence of post-concussion symptoms following the injury.

d. Post-Concussion Symptoms

Following mTBI, individuals commonly experience a constellation of symptoms referred to as *post-concussion symptoms* (PCS). These have three broad categories: physical, cognitive, and psychological (McInnes et al., 2017). Physical symptoms include headaches, light and sound sensitivity, dizziness, poor balance, lack of coordination, visual difficulties, fatigue, low energy, nausea, and possible vomiting (McInnes et al., 2017). Cognitive symptoms comprise of decreased response time, difficulty with attention and concentration and memory impairment concerning events pre and post injury (McInnes et al., 2017). Psychological symptoms consist of experiencing anxiety, irritability, difficulty with emotional regulation and depression (Lundin et al., 2006). Additionally, people with mTBI often experience difficulties with sleep, such as falling asleep, staying asleep or sleeping excessively (Schoenberg & Scott, 2011). For some, these acute symptoms can be

very debilitating requiring support from family members including community agencies and time off work or school (Pozzato et al., 2020).

2. Post-Concussion Symptoms

a. Persistent Post-Concussion Symptoms

It has been stipulated that the normal recovery time for those who have sustained a mTBI is generally three-months (Belanger et al., 2005; Shorer & Apter, 2016). Those who experienced lingering symptoms were deemed the 'miserable minority' of people (Ruff et al., 2009; Wood, 2004). Historically, lingering symptoms were termed as post-concussion syndrome, however, currently a syndrome-based conceptualisation is less respected than a symptom focused approach (Rickards et al., 2020; Silverberg & Iverson, 2018). This is due to the symptom sequela not being unique to mTBI thereby, it is not considered a syndrome (Rickards et al., 2020). Recent evidence has argued against the premise that only a small portion of people experience persistent post-concussion symptoms (PPCS) (Nelson et al., 2019; Balenger et al., 2013). Large longitudinal cohort studies, with selection bias, have found that nearly 50% of those with mTBI can experience persistent symptoms beyond the timeframes historically stipulated (Dikmen et al., 2017; McInnes et al., 2017; McMahon et al., 2014; Theadom et al., 2016; Barker-Collo et al., 2016; Barker-Collo et al., 2013; Nelson et al., 2019; Balenger et al., 2013; Cancelliere et al., 2014; Iverson et al., 2012). For example, a recent cross-sectional study by Bedaso et al. (2018) with a sample size of 289, found that PPCS were prevalent in 41.5% of the participants. The most prevalent symptoms experienced were headaches, restlessness, noise sensitivity and sleep disturbances (Bedaso et al., 2018). Furthermore, Nelson et al. (2019) found that 53% of the 1453 participants in their study experienced persistent symptoms resulting in functional limitations 12-months post injury. These findings suggest that contrary to

previous beliefs, mTBI recovery is ongoing consisting of persisting symptoms that cause functional impairments. These findings highlight the importance of having a better understanding PCS and the mechanisms that underlie this development thus improving long-term outcomes.

b. Prevalence

There is no clear consensual definition of persistent symptoms that occur post the expected time frame after sustaining a mTBI. There are several definitions of PPCS. For example, the International Statistical Classification of Diseases and Related Health Problems (ICD-10), defines persistent symptoms as “postconcussionnal disorder (PCD)” (Lagacé-Legendre et al., 2021). The Diagnostic and Statistical Manual of Mental Disorders (DSM-IV) as “persistent symptoms” which was followed by “major or mild neurocognitive disorder” in the DSM-V (Lagacé-Legendre et al., 2021). These various definitions and diagnostic criterions are faced with criticism due to the lack of empirical support and low reproducibility between the different sets of criteria (Lagacé-Legendre et al., 2021). Consequently, attaining a prevalence rate for PPCS is challenging (Rickards et al., 2020). In addition to the diversity in diagnostic criteria, variability in prevalence rates may also be impacted by the methodologies and sampling methods used, and the diversity of the symptoms experienced over time (Rickards et al., 2020).

c. Etiology

The etiology of PPCS is not linear, rather complex and heterogenous (Silverberg & Iverson, 2011). A multitude of factors have been identified as contributing to the development of PPCS after mTBI (Silverberg et al., 2015). Some experts believe that PPCS is caused by biological changes, such as by structural damage in the brain or by the

disruption of the messaging systems within the nerves caused by the sustained injury (Pearce et al., 2019). Consequently, injury severity has commonly been considered a risk factor in the development of PPCS (Blyth & Bazarian, 2010; Fure et al., 2021). However, research has identified that injury severity does not consistently predict outcomes (Silverberg & Iverson, 2011; Wijenberg et al., 2020; Fure et al., 2021). For example, van der Naalt and colleagues (2017) conducted an observational cohort study consisting of 910 patients and found that injury severity did not predict long-term outcomes. The study found that psychological factors such as maladaptive coping mechanisms and emotional distress experienced early after the injury, in amalgamation with pre-injury mental health, education and age, were the main predictors of mTBI prognosis (van der Naalt et al., 2017; Iverson et al., 2017; Rickards et al., 2020; Scott et al., 2016a).

Empirical evidence suggests that PPCS are more strongly related to psychological factors (Ponsford et al., 2019; Ponsford et al., 2000; Rickards et al., 2020; Silverberg & Iverson, 2011; Silverberg et al., 2015; Snell et al., 2015; Faulkner et al., 2021a; Faulkner et al., 2020; Cassetta et al., 2021; Cnossen et al., 2017; Broshek et al., 2015; van der Naalt et al., 2017; Scott et al., 2016a). For example, Rickards et al. (2020) performed a meta-analysis study and collected a broad and comprehensive model of predisposing, precipitating and perpetuating factors related to the development of PPCS. Rickards and colleagues (2020) found that predisposing factors included premorbid intellect, psychiatric illnesses and personality traits. Extensive research supports this and has found that pre-injury psychiatric issues, such as depression, neuroticism and anxiety increase the risk of PPCS significantly (Rickards et al., 2020; Faulkner et al., 2020; Cassetta et al., 2021; Cnossen et al., 2018). Furthermore, a systematic review of prognostic models of mTBI recovery found that pre-injury mental health was the strongest risk factor of incomplete recovery after mTBI (Silverberg et al., 2015). This finding was further supported by

Meares et al. (2008), who revealed that depression and anxiety increased the risk of developing PPCS more than those who did not experience pre-injury mental health. These findings suggest that pre-injury mental health can significantly contribute to poor prognosis post-mTBI.

In addition to mental health history, research has found that personality traits may increase the risk of developing PPCS (Rickards et al., 2020; Dischinger et al., 2009; Luis et al., 2003; Morgan et al., 2015; Ponsford et al., 2012; Ponsford et al., 2000; Trinh et al., 2020; Scott et al., 2016a). This appears reasonable because personality traits such as negativistic, depressed, anxious, dependent, somatic, sadistic and borderline are also strongly associated with psychiatric issues such as depression, anxiety and PTSD (Michon et al., 2008). In fact, these traits have also been found to be associated with PPCS (Merz et al., 2019; Garden et al., 2010; Ponsford et al., 2012; Ponsford et al., 2000; Morgan et al., 2015). Arguably, these personality traits can affect a person's ability to interpret symptoms experienced post-concussion (Karr et al., 2020). However, it is often difficult to distinguish whether the impact of the mTBI developed psychiatric problems or whether the pre-existing problems became exacerbated through the injury. A systemic review conducted by Carroll et al. (2014) identified that post-mTBI psychological problems reflected pre-morbid personality traits and were not the effects of the injury. This finding demonstrates a link between personality traits and PPCS, further suggesting that pre-injury psychological factors significantly influence outcomes after mTBI.

Post-injury psychological factors have also been found to predict PPCS (Rickards et al., 2020). Following mTBI, psychological distress (i.e., anxiety, depression) is not uncommon (Carroll et al., 2014; Rickards et al., 2020; Silverberg & Iverson, 2011). Many tasks for someone with mTBI can be challenging due to issues with concentration, memory, light-sensitivity, headaches and sleep difficulties (Ma et al., 2014). These

symptoms can for example, increase anxiety as an individual may experience worry about making mistakes, failing at tasks or feels pressured to return to work or school (Ma et al., 2014). Prevalence estimates for emotional symptoms such as anxiety, depression and irritability range from 49-63% following a mTBI (Silverberg & Iverson, 2011).

In fact, anxiety is the second most common diagnosis following a mTBI (Stein et al., 2019). The prevalence of anxiety disorders post-injury such as generalised anxiety disorder (GAD) (8-24%), panic disorder (2-7%), specific phobia (25%), social phobia, obsessive-compulsive disorder (OCD) (1-9%) and PTSD (0-42%) are significant (Schoenberg & Scott, 2011). However, there are limited neuropsychological findings that explain why mTBI can increase the likelihood of developing anxiety and depression (Stein et al., 2019). Given how anxiety can co-occur with mTBI, early intervention would decrease poor prognosis of recovery.

These behaviours result in precipitating symptom exacerbation via increased anxiety and negative perceptions regarding mTBI recovery (Rickards et al., 2020). These thinking styles are also consistently found in individuals with certain types of personality traits or mental health issues as discussed above. A prospective study by Hou et al. (2012) identified that negative injury perception, anxiety and all-or-nothing thinking, appeared to be strong predictors of PPCS at three-month post-injury assessment. These predictors remained present at the six-month post-injury survey with the addition of stress and depression (Hou et al., 2012). The terminology ‘traumatic brain injury’ itself was found to increase the negative perceptions of an individual’s condition hence prolonging and increasing their existing symptomology (Roth & Spencer, 2013). Roth and Spencer (2013) therefore, suggested in a recent review that educating patients that full recovery is anticipated will decrease the risk of PPCS. This finding suggests that early intervention in

addition to an individual's illness perception is significant in predicting recovery prognosis.

Anxiety and depression combined play a significant role on the development of PPCS. A growing amount of evidence has repeatedly indicated that pre-injury mental health such as anxiety and depression predict the risk of PPCS (Rickards et al., 2020; Bryant et al., 2010; Reuben et al., 2014; Carroll et al., 2004; Ponsford et al., 2019; Ponsford et al., 2012; Faulkner et al., 2020; Garden et al., 2010; van deer Naalt et al., 2017; Silverberg & Iverson, 2011; Broshek et al., 2015; Silverberg et al., 2015). For example, a cluster randomised trial study by Ponsford et al. (2019), collected data from 343 participants and found that pre-injury psychological issues were associated with experiencing persistent symptoms. According to the results, individuals who had anxiety and depression were 2.99 times more likely to report PCS at a six-months-follow up than the control group who did not experience pre-existing mental health prior to injury (Ponsford et al., 2019). Furthermore, a longitudinal observational cohort study conducted in Perth, Western Australia confirmed that mental health status, prior to injury increased the risk of developing PPCS (Gozt et al., 2021). Currently, despite rigorous examination, causality between pre-injury mental health and PPCS has not been found (Silverberg et al., 2015). There are several explanations for this outcome. Psychiatric symptoms may be caused due to experiencing PCS. Or diversly, anxiety and depression may increase the risk of reporting persisting symptoms. Consequently, future prognostic studies may benefit from applying a broader range of biopsychosocial predictors in a large inception cohort.

d. Biopsychosocial Model of Persistent Post-Concussion Symptoms

As a result of the role psychological factors play in mTBI recovery, recent literature has proposed that both biological and psychological factors contribute to the

development of PPCS (Wijenberg et al., 2021). Biopsychosocial models have been extensively used to explain the conceptualisation of mTBI and why some individuals experience persistent symptoms by highlighting the combined effects of biological and psychological factors. In accordance with the biopsychosocial model, commonly identified prognostic factors which influence PPCS, include previous history of psychiatric problems, female gender, age, injury severity, migraine/headaches, previous TBIs, illness identity and psychosocial factors (Ponsford et al., 2019; Rickards et al., 2020; Polinder et al., 2018). A recent model by Polinder et al. (2018) demonstrates the interconnection between several constructs to provide a comprehensive and detailed understanding of PPCS development. The model stipulates how pre-injury factors, injury characteristics, PCS and outcomes interplay with post-injury factors, and commonly experienced comorbid disorders (overlapping symptoms) impacting PCS and recovery. For example, pre-injury factors such as TBIs, physical and mental health, social factors, and sex have been observed to impact post-injury factors such as maladaptive beliefs, coping mechanisms, social and family networks, and perceived burden or stress (Polinder et al., 2018). This implies that an individual's pre-injury coping style is linked with mTBI recovery (Snell et al., 2015). Maestas et al. (2014) discovered that pre-injury use of avoidant coping methods was related to emotional functioning and quality of life three-months post-injury within the mTBI sample. This suggests that coping and recovery are strongly influenced by cognitive functions. Additionally, 'pre-injury factors' also impact overlapping symptoms (i.e., depression, anxiety, PTSD) and injury characteristics such as biological outcomes (i.e., diffuse axonal injuries) (Polinder et al., 2018). Overall, injury characteristics impact PCS and in turn outcomes such as functional status in somatic, emotional, behavioural and cognitive domains.

As portrayed, mTBI prognosis is neither, physiological nor psychological. In fact, neurobiological and psychological factors play a causal role in PCS (Silverberg & Iverson, 2011). This suggests that biological and psychological factors are not mutually exclusive, rather intertwined. For example, both post-injury factors and overlapping symptoms impact the severity of PCS which directly impact outcomes that involve quality of life or return to school or work. Interestingly, many PCS such as sleep difficulties, irritability and concentration problems are similar to symptoms of PTSD. According to Scholten et al. (2016) the prevalence rate of PTSD following a mTBI is noteworthy. Therefore, identifying and targeting PTSD symptoms (PTSS) is important in improving mTBI outcomes.

3. Post-Traumatic Stress Disorder

a. Post-Traumatic Stress Disorder

PTSD is a mental health condition triggered by a terrifying or life-threatening event (Sadock et al., 2015). Events which can cause PTSD include combat exposure, sexual violence, childhood abuse, physical assault, being threatened with a weapon and accidents (Sadock et al., 2015).

b. Diagnostic Criteria and Symptom Presentation

The diagnostic criteria for PTSD described in the Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition (DSM-V), of the American Psychological Association (APA, 2013) states that traumas must be witnessed or experienced by the individual. Other requirements include, displaying altered cognitions such as negative

moods and thoughts, reexperiencing the event(s), displaying avoidant behaviour, experiencing increased arousal symptoms and dissociation (APA, 2013).

To be diagnosed with PTSD, symptoms must develop a month or several years after the event (Pall, 2001). Any immediate adverse reactions to a traumatic event would be classified as Acute Stress Disorder (ASD) (Bryant & Harvey, 1998). By definition, ASD is a temporary mental health condition lasting around three to thirty days immediately following a traumatic experience in a person's life (Bryant & Harvey, 1998). If the effects and symptoms persist beyond a month, the individual will likely be diagnosed with PTSD (APA, 2013). PTSS cause significant distress and impact relationships including social, personal and occupational functioning (Sadock et al., 2015). PTSS are commonly grouped into four categories: intrusive memories, avoidance, negative changes in thinking and mood, including changes in physical and emotional reactions (Sadock et al., 2015). For example, intrusive memories may include experiencing recurrent, unwanted distressing memories of the traumatic event, reliving the event through flashbacks, having nightmares, or suffering severe emotional anguish and physical reactions caused by the event (APA, 2013; Sadock et al., 2015). Avoidance can involve avoiding people, places, things, or memories that are reminders of the trauma (APA, 2013; Sadock et al., 2015). Cognitive changes entail distressing thoughts and feelings such as shame and guilt. Lastly, PTSD can cause hyperarousal such as increased alertness, anger, fits of rage, irritability, or hatred, flat affect and difficulty sleeping or concentrating (Sadock et al., 2015). PTSD can be extremely debilitating and has been observed to implicate physical health outcomes, increasing the risk of illnesses or deteriorating existing ones (Sadock et al., 2015).

c. Prevalence

The prevalence of PTSD is increasing as more children, adolescents and adults are becoming exposed to traumatic events (Elliot et al., 2021). The lifetime incidents of PTSD are approximately 9-15% including a lifetime prevalence rate of 8% regarding the general population, with 5-15% of individuals experiencing a subclinical form of PTSD (Sadock, et al., 2015). These findings indicate that PTSD is common and can affect individuals from all ages, genders, and cultures.

d. Etiology

PTSD has a broad and heterogeneous etiology with a range of biological, social, psychological and environmental influences (Elliot et al., 2021; Pall, 2001; Bryant et al., 1998; Sadock et al., 2015). Predisposing factors include inadequate family or peer support, exposure to early adverse childhood events (ACES), personality disorder traits (borderline, anti-social or dependent), gender (female), genetic vulnerability to psychiatric illnesses and recent stressful life changes (Sadock et al., 2015). Additionally, according to Elliot et al. (2021) PTSD is rarely caused by a single factor, rather research demonstrates that PTSD is a "multicausal" phenomenon (Hu et al., 2020). PTSD is the outcome of several potential causes which may or may not trigger symptoms of PTSD until later life, or until significant stressful events (stressors) precipitates the disorder (Elliot et al., 2021). Rather than describing the factors that contribute to the development of PTSD as "causes" the focus has shifted to describe them as "risk" and "protective" factors (Sadock et al., 2015). Interestingly, 80-90% of people who do encounter traumatic event(s) do not develop PTSD (Elliot et al., 2021). This finding has inspired rigorous research to better understand the conceptualisation of PTSD through formulating models.

e. Models of Post-Traumatic Stress Disorder

The diathesis stress model suggests that PTSD is a combination of biological, genetical, psychological and social factors all of which indicate a strong link between nature and nurture being inherent in the causation of PTSD (Sadock et al., 2015). Eberhart and Hammen (2010) stated that people inherit tendencies to express specific traits or behaviours under stressful conditions, explaining why some people do and do not develop PTSD. These tendencies, specific traits or behaviours include negative thinking styles (i.e., all-or-nothing thinking, generalisation, catastrophising), avoidance behaviours and maladaptive coping styles such as substance abuse (Eberhart & Hammen, 2010). This model postulates that overall, our genetic make-up predisposes an individual to their responses (Eberhart & Hammen, 2010). Responses are arguably behavioural outcomes, as literature commonly depicts that PTSD stems from a behavioural response, as such making it unique to individuals.

Empirically validated etiological models of PTSD are commonly informed by behavioural principles, which focus on conditioned reactions to trauma-relevant stimuli (Hassija & Gray, 2007). Followed by acknowledging the prominent role that avoidant coping behaviours play in maintaining or exacerbating conditioned fear and anxiety responses to trauma cues and contexts (Hassija & Gray, 2007). For example, it is common for individuals who experienced a trauma to avoid all trauma related stimuli to circumvent triggering memories associated to the incident. However, because triggers are often unpredictable, and can occur at any given moment, avoidance thus becomes a primary coping mechanism (Pall, 2001).

As seen, there is a strong interplay between cognitive and behavioural components which result in development and maintenance of PTSD (Lancaster et al., 2011). Additionally, there is an interaction between the learning and conditioning of elements,

plus a focus on memories and information processing upon which an individual's reactions are influenced by (Lancaster et al., 2011). This theory is in line with Ehlers and Clark's formulation of PTSD. A cognitive model that pursues to explain the tenacity of PTSS while presenting a framework in the design of cognitive-behavioural treatment for the illness. This model proposes that the pathological response to trauma is increased when the individual processes the traumatic experience and/or its moments, consequently causing a continuum of sensations that cause the individual to experience 'a sense of threat', thereby eliciting strong emotional reactions (Ehlers & Clark, 2000). The model posits that the sense of threat arrives from the traumatic event, the nature of the trauma memory and the negative appraisal of the event and its consequences (Ehlers & Clack, 2000). This response creates a cycle of a continuous sense of fear/threat that is based on the appraisal process. The appraisal theories of emotions suggest that our feelings are extracted from our evaluations (appraisals or estimates) of events that cause specific reactions in different people (Ehlers & Clark, 2000). These appraisals can stem from the nature of the event such as the ideology that "nowhere is safe" thus engaging in the second concept of the model, upon which the individual develops coping mechanisms such as avoidance (Ehlers & Clark, 2000). There are several avoidance-based strategies that can include avoidance both of situations connected to the trauma and of emotions and emotion-provoking cognitions (Ehlers & Clark, 2000). These practices aim to alter cognitive change processes which elevate an individual's cycle of 'sense of threat' (Ehlers & Clark, 2000). This cycle traps an individual to experience the event at the forefront of their thinking despite the great attempts to avoid this situation. Evidently, avoidance as a coping mechanism creates harm rather than providing an escape.

4. Mild Traumatic Brain Injury and Post-Traumatic Stress Disorder

a. mTBI Increase the Risk of PTSD

Sbordone & Liter (1995) once documented that mTBI did not cause PTSD. However, current research has refuted that premise and found that mTBI significantly increases the risk of PTSD development (Rickards et al., 2020; Polinder et al., 2018; Stein et al., 2019; Bryant, 2011; Bryant et al., 2010; Bryant, 2018; Zatzick et al., 2002; O'Donnell et al., 2004; Hoffman et al., 2012). This may be due to the emotionally traumatic nature in which some mTBI are sustained, such as through combat, assault, or motor vehicle accidents (Stein et al., 2019). The trauma in which the mTBI is attained can be the catalyst for precipitating PTSS (Stein et al., 2019). A prospective longitudinal cohort study performed by Stein et al. (2019) between February 2014 to May 2018, found several risk factors involved in the development of PTSD following a mTBI. The study had a total of 1155 civilian participants with a mTBI (GCS score, 13-15) and 230 patients with non-head orthopaedic trauma injuries. These participants were assessed at three, six and 12-months post-injury intervals. The results of PTSD at three-months assessment was 20.0% compared with 8.7% in the non-head injury group, and at six-months those percentages were 21.2% and 12.1%, respectively (Stein et al., 2019). Several risk factors were found to increase the development of PTSD, such as lower education, race/ethnicity, gender, pre-injury mental health, and injury as the result of assault or other violence (Stein et al., 2019). These findings indicate that mTBI increases the risk of PTSD and provides insight into identifying individuals who are at a higher risk of developing PTSS, thus informing early intervention practices.

b. Prevalence

The prevalence of PTSD in mTBI populations is challenging to attain for several reasons. There is a lack of objective markers for mTBI and PTSD (Sloley, 2020). There is

significant symptom overlap between mTBI and PTSD (Wolf et al., 2020; Carlson et al., 2011) and lastly, the prevalence of mTBI and PTSD can vary depending on the populations assessed (Sloley, 2020). Interestingly, PTSD following a mTBI has a pooled prevalence rate of 13.8% (Scholten et al., 2016; Bryant, 2011). Findings in literature range between 10.2% to 17.4 % (Scholten et al., 2016; Bryant, 2011). Additionally, PTSD appears to occur more frequently after TBI than in other traumatic injuries not involving the brain (Bryant, 2011; Bryant, 2018). A significant portion of literature concerning the prevalence rate of PTSD in mTBI populations focuses on veterans (Wolf et al., 2020), as such, literature reflects a high overlap rate within this population. Numerous studies aimed at determining the prevalence in civilian populations have encountered conflicting results demonstrating challenges to standardise and compare the mechanisms and circumstances of injury characteristics (Sloley, 2020). Despite these limitations, there is significant literature that demonstrates high rates of PTSD post-mTBI in various populations. A recent meta-analysis aimed at identifying the prevalence of comorbid PTSD and mTBI, found that their co-occurrence in civilian samples was approximately 13.5% (Sloley, 2020). The meta-analysis also found that mTBI is more commonly associated with PTSD than moderate or severe TBI in civilian populations (Sloley, 2020). Furthermore, examinations of military populations through systemic reviews, revealed that comorbid mTBI and PTSD was significantly more common in military than civilian individuals (Van Praag et al., 2019). The systemic review compared the results and found that 11-18.6% of civilians who sustained a mTBI developed PTSD symptoms within two years of injury, whereas 48.2% of veterans developed PTSD after mTBI (Van Praag et al., 2019). This evidence suggests that PTSD after a mTBI can and does co-occur in both civilian and military populations (Wolf et al., 2020; Van Praag et al., 2019).

It has been proposed that the development of PTSD post-mTBI can be attributed to how an individual responds in the early stages post-mTBI. Harvey and Bryant (1998) conducted a two-year prospective evaluation focusing on the relationship between ASD, PTSD and mTBI. Individuals where assessed a week post-injury and at six-months follow up. According to the results, if ASD was present at seven days post-injury, 82% of individuals had developed PTSD at the six-months follow up (Harvey & Bryant, 1998). In comparison, those who did not have ASD at study entry, resulted in 89% being PTSS free six-months later. A follow up study by Harvey and Bryant (2000) presented similar patterns at two-years post-injury. These findings suggest high stability of PTSD from the acute chronic phase shortly after sustaining mTBI. In contrast, Meares et al. (2011) found that the relationship between severity of PTSS and PCS was 2.66 times stronger at three-months follow up than at the initial assessment five days post-injury. However, this study had major methodological flaws (most notably, the timing of the assessments) which have been proposed to explain this discrepancy. A more recent study by Schneiderman et al. (2008) researched a sample of soldiers who presented with overlapping symptoms of mTBI and PTSD and further compared mTBI and PTSD in the general population. Schneiderman et al. (2008) observed that there are approximately one in four cases in the general population experiencing mTBI and PTSD. Additionally, Schneiderman et al. (2008) found that ASD symptoms could predict PTSD if they were low to moderate in severity at six-months post-injury. Similar findings of an association between ASD and PTSD including persistent symptoms (i.e., PPCS) can be found elsewhere (Rickards et al., 2020). It could be anticipated that subclinical symptoms consistent with PTSD may be contributory. As such these symptoms can be experienced in all populations, suggesting that the overlap is not limited to military populations (Schneiderman et al., 2008).

c. Increased Levels of PTSD Impact mTBI Recovery

A cross-sectional cohort study by Vanderploeg et al. (2009) found that higher levels of PTSS increased the period of recovery from mTBI. There have been several proposed explanations to account for the role of PTSD in the maintenance of symptoms after mTBI. Firstly, Vanderploeg et al. (2009) found that PTSD and mTBI feed and reinforce each other. For example, mTBI increases the severity of PTSS (Amick et al., 2013; Heilbronner, 2012). In turn higher PTSS increase the risk of individuals developing comorbid mental illnesses such as depression and anxiety, increasing the risk of developing PPCS (O'Connor & Drebing, 2011). Hoyland and Raskin (2000) found that post-mTBI the emergence of PTSS increases the risk of PPCS including cognitive deficits. Cognitive deficits in turn implicate the recovery process and may cause additional symptomologies which either perpetuate or exacerbate the conditions (Wijenberg et al., 2021). For example, neuropsychological findings found deficits in both PTSD and mTBI (Lew et al., 2009). These deficits are found in attention, verbal memory and response inhibition (Lew et al., 2009). The cognitive deficits in PTSD were found to be less severe than in mTBI populations who experience changes in intelligence quotient (IQ), have deficits with memory, processing speed, and executive functioning (Santhanam et al., 2019). Experiencing these deficits increases an individual's somatic symptoms, such as headaches, dizziness, tinnitus, disequilibrium, irritability and hypervigilance (Lew et al., 2009). These symptoms intensify PTSD severity, by increasing emotional distress which in turn exacerbate the deficits and somatic symptoms hence impacting mTBI recovery.

Secondly, PTSD and PCS show high symptom overlap (Carlson et al., 2011; Hoffman et al., 2012). Consequently, symptom overlap has been presented to be a probable explanation for why PTSS impact mTBI recovery (Santhanam et al., 2019). When PTSD and mTBI coexist, differentiating between symptom presentations such as

memory and concentration, depression, anxiety, insomnia and fatigue can be difficult (Vanderploeg et al., 2009; Heilbronner, 2012). Symptom overlap has been found to increase the risk of potential misdiagnoses, exacerbation of existing symptoms and the development of other mental health disorders, which impact recovery outcomes (Huguenard et al., 2020). Differentiating the diagnoses between PTSD and mTBI, especially in individuals diagnosed with both requires care (Lew et al., 2009) and is critical for the treatment and determination of disability (Santhanam et al., 2019). The non-specificity of PPCS and the comorbidity of other mental illnesses associated with mTBI (i.e., anxiety and depression) results in frequent misdiagnosis (Sloley, 2020). A recent study found that misdiagnosis is a common occurrence among the mTBI and PTSD population (Rosen & Ayers, 2020). The consequence of misdiagnosis impacts treatment interventions provided and reduces successful outcomes for recovery. Therefore, effectively diagnosing and understanding the overlap in symptomology can guide evidence-based treatment options leading to successful recovery.

d. Differences and Similarities between PTSD and mTBI

Despite the similar symptom presentations experienced between PTSD and mTBI, such as memory difficulties, concentration deficits, depression, anxiety, insomnia and fatigue, there are slight differences (Vanderploeg et al., 2009). These differences account for how PTSD impacts mTBI recovery. Several factors have been noted to significantly affect mTBI recovery. These include injury characteristics, symptom presentations, sleep disturbances, pathophysiology, and the possibility of causation, all of which have been noted to contribute to negative outcomes.

e. Injury Characteristics and Symptom Presentation

Although an individual may sustain an mTBI and PTSD within the same event (Hoffman et al., 2012), injury characteristics and symptom presentations may differ. For example, mTBI often experience LOC or periods of amnesia, whereas PTSD is often plagued with unwanted and intrusive thoughts and memories forcing individuals to re-experience the event (O'Connor & Drebing, 2011). The occurrence of intrusive thoughts and memories frequently increases the risk of anxiety, depression and substance abuse negatively impacting mTBI recovery (Ehde & Fann, 2011). Intrusive thoughts and memories also increase avoidance behaviours. This may include self-imposed isolation to create safe confines rather than being exposed to and interacting with people or places (Gilbert et al., 2015). This method of avoidance consequently increases the risk of substance abuse and depression (Gilbert et al., 2015). Although individuals with mTBI have also been found to use avoidance methods regarding strenuous cognitive tasks, known as cogniphobia, however, they often seek support rather than self-isolate (Ehde & Fann, 2011).

f. Sleep Disturbances

Another pivotal factor to consider is sleep, an integral part of mTBI recovery (Gilbert et al., 2015). Individuals with PTSD often experience hypervigilance and flashbacks which interferes with sleep. Hypervigilance effects a person's ability to attain a mental resting state which allows sleep to occur (O'Connor & Drebing, 2011). Nightmares are a key feature of PTSD which often causes individuals to avoid going to sleep (Gilbert et al., 2015). Additionally, hypervigilance, nightmares and flashbacks are not organic to mTBI, therefore these symptoms affect mTBI recovery (Vanderploeg et al., 2009). Although mTBI do experience sleep difficulties, they are not met with nightmares or intrusive reminders of the traumatic event. Furthermore, lack of sleep causes individuals to experience fatigue (O'Connor & Drebing, 2011). As such, fatigue impacts physical,

cognitive and emotional wellbeing, increasing behaviours such as irritation, affecting concentration and increasing risk for physical injuries (O'Connor & Drebing, 2011).

g. Pathophysiology

The pathophysiology of mTBI and PTSD is complex, exhibiting similarities in the alteration of specific brain structures. These similarities have been noted to be an alternative explanation for the role of PTSD in the maintenance of symptoms after mTBI. PTSD is often associated with alterations in the hypothalamic-pituitary-adrenal (HPA) axis (Dunlop & Wong, 2019; Bremner, 1999; Schumacher et al., 2019). The HPA axis is known to be implicated in the neurobiology of mood disorders and functional illnesses (Dunlop & Wong, 2019). These illnesses comprise of anxiety disorder, bipolar disorder, PTSD, insomnia, ADHD, borderline personality disorder, burnout, major depressive disorder, irritable bowel syndrome, chronic fatigue syndrome, fibromyalgia, and alcoholism (Dunlop & Wong, 2019; Schumacher et al., 2019). Similarly, mTBI are often sustained in the frontal regions of the brain releasing a cascade of neurotransmitters, causing secondary injury, central sensitisation, and alterations of the HPA axis (Patterson, 2016). According to Russel et al. (2018) over one-third of people exposed to blast-induced TBI (bTBI) experience prolonged neuroendocrine deficits, shown by anterior pituitary dysfunction. Furthermore, studies have found dysregulation of the HPA axis with mTBI individuals which is also strongly linked to increased risk for psychiatric disorders (Russel et al., 2018). However, there is limited information on how the HPA axis responds to mTBI, including the differences between sexes (Russel et al., 2018). Abnormal connectivity within neural networks have been identified in both mTBI and PTSD individuals, however, the potential role of PTSD in changes to neural networks following a mTBI has not been studied in detail (Schumacher et al., 2019).

h. Causation

It is challenging to assess whether mental health which was already present was caused by a mTBI or whether the mTBI caused the individuals mental health (Faulkner et al., 2020). According to Rickards et al (2020) precipitating factors which contribute to PPCS do not occur in isolation and are very much influenced by a variety of factors including the event in its entirety and experience of initial symptoms which contribute to how symptoms resolve or persist (Rickards et al., 2020). This suggests that biological and psychological mechanisms are not exclusively mutual and implies that psychological mechanisms maintain biological symptoms. Although literature highlights that mTBI increase, nay predict PTSD, the question of causality remains unclear. For example, Lagardge et al. (2014) confirmed in his study that mTBI was a significant predictor for PTSD but not for PCS. This suggests that the PTSS had no effect on PCS. However, Meares et al. (2011) examined 62 people with mTBI and revealed that acute post-traumatic stress was predictive of PCS at three-months. Evidently, a relationship exists between post-injury mental health and PCS. These findings support the premise that potential psychological mechanisms are significant in the contribution of PTSD and post-concussion development following an mTBI. There is a need to treat and mitigate the development of PTSD in mTBI to improve outcomes. To achieve this, underlying transdiagnostic processes which contribute to the relationship between PTSD and mTBI need to be identified.

5. Psychological Mechanisms

a. Transdiagnostic Boundaries Contribute to Mental Health

There is a need to treat and mitigate the development of PTSD in mTBI to improve outcomes. To achieve this, underlying transdiagnostic processes which contribute to the

relationship between PTSD and mTBI need to be identified. A transdiagnostic approach to mental health is important to help practitioners examine how shared symptoms develop into disorders (Dalgleish et al., 2020). Rather than thinking of mental health diagnoses as separate conditions, practitioners now are aware that there are shared processes or mechanisms which underpin or act to maintain symptomologies (Eaton et al., 2015). Transdiagnostic processes are mechanisms that are shared across disorders which are risk or maintaining factors (Eaton et al., 2015). For example, intrusive memories can be experienced by people with diverse conditions, such as depression, anxiety, PTSD and eating disorders (Brewin et al., 2010). Repetitive negative thinking styles are mechanism which are often a feature of anxiety disorders, PTSD and mTBI (Brewin et al., 2010). Identifying the psychological mechanisms could consequently ensure that interventions are tailored to specifically target these mechanisms and thereby improve their effectiveness.

b. Fear Avoidance and PTSD

Emotional avoidance is part of the avoidance cluster of PTSS. This enables people to avoid emotionally triggering memories by avoiding activities, locations, people and memories which are strongly linked to the traumatic event. Avoidance is the central symptom to PTSD and is considered a maladaptive coping mechanism which functions to limit or decrease distress experienced by individuals (Stein et al., 2019). Early avoidance symptoms in fact have been seen to increase the risk of developing PTSD (Sripada et al., 2013). According to Sripada et al. (2013) avoiding thoughts, feelings and reminders can exacerbate and worsen the symptoms thus affecting psychosocial functioning and quality of life.

In addition to avoidance, a main characteristic of PTSD is processing and regulating fear (Norrholm & Jovanovic, 2018). Individuals with PTSD experience great difficulty with regulating their fear of trauma-associated provocations (Maeng & Milad, 2017). According to Sripada et al. (2013) there are various abnormalities in PTSD. These include overgeneralisation of conditioning, impaired extinction, fear associated learning, greater acquisition of conditioned fear and impaired inhibitory learning (Sripada et al., 2013). These deficits play a role in the development and preservation of PTSD and those abnormalities in the extinction and/or retention of conditioned fear may be especially relevant for the persistence of fear memories in PTSD (Sripada et al., 2013). Hyperarousal such as hypervigilance is a key mechanism in PTSD and is the result of a 'here and now' response to an intrusive memory (Sripada et al., 2013). According to the fear-avoidance model, hyperarousal, also commonly seen with chronic pain, has the capacity to increase pain sensations leading to fear-avoidance behaviours (Snell et al., 2019).

Maeng and Milad (2017) uncovered that memory recall and extinction learning were significantly reduced in patients with PTSD compared to trauma-exposed non-PTSD control participants. Furthermore, the study found that the impairment was restricted to the recall of the extinction memory, whereas conditioned fear acquisition and extinction learning were not disrupted in the PTSD group (Maeng & Milad, 2017). Consequently, fear and avoidance significantly contribute to the development and maintenance of PTSD. It seems to be the case that fear avoidance may be a shared mechanism that contributes to both the development of PTSD and PPCS. However, there are currently limited studies that have examined the role of fear avoidance in the relationship between PTSS and mTBI outcomes.

c. Fear Avoidance Increases Risk of PTSD in mTBI Population

One psychological mechanism which has been explored in mTBI is fear avoidance (Silverberg et al., 2018). The fear avoidance model (FAM) was originally introduced by Lethem et al. (1983) to explain how individuals developed and maintained chronic musculoskeletal pain as a result of attentional processes and avoidant behaviours based on pain-related fear. This model helped explain how individuals experience pain despite the absence of pathology (Lethem et al., 1983). For example, if an individual experienced acute discomfort and delayed the situation through an avoidant behaviour, a lack of pain increase reinforced this behaviour (Lethem et al., 1983). The sense of vulnerability from the discomfort, provides positive feedback to the perceived level of pain, thus rewarding the avoidant behaviour for removing the unwanted stimuli (Lethem et al., 1983). Consequently, the FAM is based on avoiding activities and behaviours stemmed from fear of pain or re-injury (Snell et al., 2020). Fear avoidance restricts what individuals do or modifies how they do it to prevent physical or psychological discomfort (Snell et al., 2020; Wijenberg et al., 2020; Greenberg et al., 2020). Fear avoidance is a known risk factor for chronic disability after musculoskeletal injury and has been extensively studied in various health conditions such as chronic pain, tinnitus, chronic fatigue, whiplash syndrome and fibromyalgia, as well as in cancer survivors (Wijenberg et al., 2020; Cassetta et al., 2021; Snell et al., 2019; Wijenberg et al., 2021; Greenberg et al. 2020). Although all these health conditions are different, they share a commonality that symptoms of these conditions can evolve into chronic symptomologies in only a subset of patients, like the PPCS population (Wijenberg et al., 2020). According to extensive literature, fear avoidant behaviours increase the risk of symptom persistence and disability, directly impacting many of the mentioned conditions (Snell et al., 2020; Wijenberg et al., 2020; Wijenberg et al., 2021; Greenberg et al., 2020; Cassetta et al., 2021).

There is limited research involving the role of fear avoidance on mTBI recovery. However, initial findings suggest that it may have a significant role in the development of PPCS. Silverberg et al. (2018) performed a study to research whether fear avoidance or endurance behaviour impacted mTBI outcomes. Of the 273 patients screened, 102 completed the initial assessment and 87 returned for the outcome assessment (Silverberg et al., 2018). There were two time points which were assessed. First, individuals were recruited at the clinic shortly after sustaining a mTBI and were asked to complete a battery of questionnaires that measured activity avoidance and associated fears. The follow-up assessments occurred four to five months after the initial assessment. The study found that fear avoidance predicted poor mTBI outcomes and increased the risk of depression (Silverberg et al., 2018). Avoidance behaviours after mTBI were motivated by the fear of PCS, and/or a host of other feared anticipated consequences of resuming usual pre-injury activities (i.e., cognitively demanding tasks) (Silverberg et al., 2018). Furthermore, fear avoidance was found to be associated with lower education level (Silverberg et al., 2018). This suggests that low health literacy may facilitate maladaptive illness beliefs and coping styles (Silverberg et al., 2018).

A key feature of fear avoidance is catastrophising thoughts. Catastrophising thoughts is a cognitive process characterised by a lack of confidence and control and an expectation of negative outcomes (Gatched & Neblett, 2021). Pain catastrophising is the process upon which pain is misinterpreted in a catastrophising manner (Westman et al., 2011). It has been recognised that these thoughts can lead on to pain-related fear which increase safety seeking behaviours such as avoidance (Westman et al., 2011). Therefore, the FAM posits that if an individual interprets pain as especially threatening, they begin to catastrophise, which can lead to feelings of pain-related fear and avoidance of daily activities (Greenberg et al., 2020).

Catastrophising thoughts can occur in individuals with mTBI (Wijenberg et al., 2021). For example, these individuals may misinterpret information regarding the damage to their brain, in addition to its immediate consequences in a catastrophising way (Wijenberg et al., 2017). Catastrophising results in increasing anxiety and avoidance behaviour gradually over time. The FAM stipulates that catastrophising is a mechanism that results in symptoms being wrongly interpreted leading to disproportional fear of symptoms which consequently leads to avoidance behaviour, worsening over time. Greenberg et al. (2020) tested the strength and reliability of pain catastrophising and avoidant behaviours in relation between anxiety and PPCS among patients with mTBI. The results indicated the importance of developing interventions to directly target anxiety for pain catastrophising and for activity engagement despite avoidance to decrease symptom severity among patients with mTBI (Greenberg et al., 2020).

The most common form of catastrophising is related to behavioural avoidance of cognitively challenging tasks commonly known as cogniphobia. For example, fear of mental exertion inducing headaches post-mTBI is associated with reduced memory performance and other forms of avoidance behaviour (Silverberg et al., 2018). Avoidance behaviour may be adaptive in the acute phase, it can contribute to disuse, disability and depression which paradoxically worsen the symptoms in later stages (Wijenberg et al., 2017). More importantly the FAM suggests that the severity of the injury is not a definite predictor of PPCS. Rather it is the psychological factors such as catastrophic thinking and fear avoidant behaviours, initiated by a biological injury which increase the risk of developing PPCS (Wijenberg et al., 2017).

Fear avoidance in addition to predicting disability in mTBI individuals, also increases the risk of developing anxiety disorders and depression (Wijenberg et al., 2020). Avoiding aversive thoughts or emotions can contribute to psychopathology (Silverberg et

al., 2018). mTBI often occur in emotionally traumatic contexts and require emotional adaptation to the changes that occur in response to the event (Wijenberg et al., 2020). This process subsequently results in progressive symptoms of depression, reduction in mental activities (disuse), and enhanced functional disability (e.g., decreased ability to perform daily life activities such as work or social activities). This could, in turn, increase the number and magnitude of symptoms, concluding their cyclic pattern (Wijenberg et al., 2020). Given that fear avoidance increases negative outcomes in mTBI and increases the risk of psychopathology, could also indicate a possible risk for PTSD.

d. Psychological Flexibility and PTSD

Psychological flexibility is a central concept for an individual's health and wellbeing. Having psychological flexibility benefits individuals to adapt to changing situational demands (Kashdan & Rottenberg, 2010). Furthermore, psychological flexibility allocates mental resources, shifts perspectives, and finds balance amongst competing demands (Kashdan & Rottenberg, 2010). Broadly speaking, psychological flexibility entails three components. Firstly, openness: the capacity to persist or to change behaviour in a conscious way which recognises one's thoughts and feelings (Kashdan & Rottenberg, 2010). Secondly, awareness: the ability to show and appreciate what the situation affords (Kashdan & Rottenberg, 2010), and lastly, engagement: to serve one's goals and values (Kashdan & Rottenberg, 2010). Psychological flexibility allows a person to be more receptive and open to experiences of discomfort from both internal and external experiences (Kashdan & Rottenberg, 2010). Moreover, psychological flexibility mitigates avoidance, and permits an individual to behave in accord with values, despite the possibility for encountering difficult or uncomfortable sensations (Kashdan & Rottenberg, 2010).

Comparatively, psychological inflexibility has an overarching influential role in contributing to psychopathologies. Psychological inflexibility has been associated with poor psychological health (Bond et al., 2011; Masuda & Tully, 2012), such as eating disorders (Chiesa & Serretti, 2010), depression (Bohlmeijer et al., 2011), anxiety and pathological worry (Hayes et al., 2006), psychosomatic symptoms (Leonidou et al., 2019), chronic pain (McCracken & Morley, 2014), psychosis (Moitra & Gaudiano, 2016) and substance abuse (Luoma et al., 2011). High levels of psychological inflexibility can result in the rigid implementation of negative psychological factors such as rumination, impulsivity and health outcomes such as psychological distress, pain and fatigue which result in the maintenance of psychological symptoms (Morris & Mansell, 2018). It is therefore not surprising that pre-injury mental health is a significant risk factor for PCS (Faulkner et al., 2020) and PTSS (Schramm et al., 2020).

In fact, psychological inflexibility predicts PTSS (Schramm et al., 2020; Meyer et al., 2019) and psychological distress (Whiting et al., 2015). A recent study by Meyer et al. (2019) examined whether higher levels of psychological inflexibility predicted PTSS severity. They found in their one-year follow up that individuals who had higher levels of psychological inflexibility were experiencing higher PTSS severity (Meyer et al., 2019). This finding supports that psychological inflexibility contributes to PTSS development. Arguably this may be because psychological inflexibility is characterised by cognitive fusion (entanglement with unhelpful thoughts and taking one's thoughts as representing reality) and experiential avoidance (avoiding unpleasant thoughts, feelings and memories) (Schramm et al., 2020). Avoidance, intrusive thoughts, arousal and negative alterations in cognition and mood are integral to both PTSD and PCS (Hayes et al., 2006). Consequently, psychological inflexibility has been observed to be a shared mechanism

that contributes to the development of PTSD (Schramm et al., 2020) and PCS (Faulkner et al., 2021a).

Many PCS such as sleep difficulties, irritability and concentration problems are also symptoms experienced in PTSD (Gilbert et al., 2015; O'Connor & Drebing, 2011; Ehde & Fann, 2011), potentially suggesting that treatment should address psychological flexibility in the early stages of mTBI to minimise the risk of developing PCS. A recent study indicated that PTSS indirectly predicts the expression of externalising behaviours via negative urgency, catastrophising, or the propensity to act rashly in the situation of distress (Dutra & Sadeh, 2018). The study used acceptance and commitment therapy (ACT) to increase psychological flexibility and found that this psychological mechanism reduced and moderated negative urgency, catastrophic thinking and aggressive behaviour (Dutra & Sadeh, 2018). This finding supports that psychological flexibility can mitigate the negative outcomes of PTSD.

e. Psychological Flexibility Increases the Risk of PTSD in mTBI Population

Given these findings, a strong rationale is being built for empirically investigating psychological flexibility in mTBI recovery. Exploring this role is undeniably necessary due to the lack of research in this field. Arguably, this could be due to psychological inflexibility being the pathophysiological effect of an mTBI. Identifying what regions of the brain are involved in psychological flexibility is complex, with limited information (Faulkner et al., 2020). Based on current evidence, it can be hypothesised that the structures within the frontal lobes such as the anterior cingulate cortex, medial and orbital frontal cortex are important (Faulkner et al., 2020). These regions are also commonly involved in the pathophysiology of mTBI (Faulkner et al., 2020). This may suggest that the impact of injury may implicate psychological flexibility. However, considering

psychological inflexibility is strongly associated with psychopathology and PCS often an outcome of pre-injury mental health, may suggest that psychological inflexibility for some individuals becomes more exacerbated by mTBI related pathophysiology and cerebral dysfunction in the prefrontal lobes, cortical regions which appear to be associated with psychological flexibility (Faulkner et al., 2020).

According to Whiting et al. (2017) people often display psychological distress after sustaining an mTBI, which can present as depression (Bombardier et al., 2010), anxiety (Gould et al., 2011), irritability (Alderman, 2003) and anger (Baguley et al., 2006). Additionally, people can struggle with self-identity problems, as the person struggles to come to terms with their post-injury self (Myles, 2004). Whiting and colleagues (2015) found that higher levels of psychological inflexibility were indicative of increased levels of distress. This finding further supports the case showing that psychological inflexibility strongly contributes to psychopathologies.

Furthermore, psychological flexibility is a pivotal psychological mechanism that contributes to mTBI recovery (Faulkner et al., 2020; Whiting et al., 2015, 2017). A recent study by Faulkner et al. (2021a) investigated the role of psychological flexibility in mTBI recovery. Additionally, the study examined whether psychological flexibility had a unique contribution to PCS and functional status. The study recruited participants from the North Island of New Zealand between March and September 2020. A total of 169 (18 years and over) were recruited. Both clinical and demographic variables were attained, and participants were asked to complete self-report measures of PCS, psychological distress (anxiety, stress and depression) and functional status within four weeks of entry to an mTBI outpatient clinic. In addition, participants were also asked to complete a general measure (Acceptance and Action Questionnaire), as well as a context-specific (Acceptance and Action Questionnaire—Acquired Brain Injury) measure of psychological flexibility.

Using linear regression analysis Faulkner and colleagues (2021a) found that psychological flexibility made a significant contribution to the prediction of PCS and functional status. Furthermore, a series of multiple mediation analyses found that psychological flexibility had a significant indirect effect on the relationships between PCS and functional status.

6. How these Mechanisms Inform Treatment

Shared psychological mechanisms are seen across various disorders. More specifically within PTSD and PCS. Understanding the relationships, contributions or predictive potentials between fear avoidance, psychological flexibility, PTSS and mTBI outcomes is imperative due to the major gap in empirically validated psychological interventions targeting psychological vulnerabilities. Enhancing outcomes, such as reducing PCS and improving quality of life would reduce the increasing costs associated to mTBI recovery. A treatment option, which targets these shared mechanisms is ACT. ACT is a type of psychotherapy which helps individuals accept difficulties that come with life, focusing directly on psychological flexibility (Hayes et al., 2016). Numerous studies have indicated the effectiveness of ACT in reducing inflexible behavioural responses (maladaptive coping mechanisms, rumination) (Hann & McCracken, 2014; Veehof et al., 2011) across several chronic health conditions such as pain, tinnitus, and general psychological distress (Dahl et al., 2004; McCracken et al., 2013; Westin et al., 2008; Fledderus et al., 2021). The core conception of ACT is that psychological suffering is usually caused by experiential avoidance thereby targeting fear avoidance, while simultaneously increasing psychological flexibility by adapting to the changes. Considering both have been identified to be robust predictors of exacerbating and maintaining symptomologies such as PTSD and PCSS, it is therefore not surprising that this study will assess whether these psychological mechanisms contribute to the following hypotheses explored in this research.

7. Summary and Research Questions

For the purpose of this study there will be three research questions. First, the role of PTSS on mTBI outcomes will be explored. To achieve this, the relationship between PTSS and mTBI functional outcomes will be investigated. It hypothesised that after mTBI individuals with higher PTSS will have higher PCS and lower functional disability. In addition, to account for the impact of confounding variables on this relationship, linear regression will be computed to investigate if PTSS will make a unique and significant contribution to mTBI outcomes. It is further hypothesised that even when accounting for the impact of these confounding variables, PTSS will continue to make a significant and unique contribution to PCS and functional status in individuals with mTBI.

Second, the role of the psychological mechanisms, psychological inflexibility, fear avoidance, and PTSS in individuals with mTBI will be explored. To achieve this, the relationship between these psychological mechanisms and PTSS will be investigated. It is hypothesised that there will be a significant positive relationship between psychological inflexibility and fear avoidance and PTSS. That is, higher levels of psychological inflexibility and fear avoidance will be associated with greater PTSS in individuals with mTBI. In addition, to account for the impact of confounding variables on this relationship, linear regression will be computed to investigate if these psychological mechanisms will make a unique and significant contribution to PTSS. It is further hypothesised that even when accounting for the impact of these confounding variables, psychological flexibility and fear avoidance will continue to make a significant and unique contribution to PTSS in individuals with mTBI.

Finally, the role of psychological flexibility and fear avoidance as underlying psychological mechanisms that contribute to the relationship between PTSS and mTBI

outcomes will be explored. To achieve this, mediation analyses will be computed to investigate the indirect effect of psychological flexibility and fear avoidance on the relationship between PTSS and PCS, as well as functional status. It is hypothesised that psychological flexibility and fear avoidance will independently have a mediating effect on the relationship between PTSS and mTBI outcomes.

Chapter Three: Methodology

This research is a quantitative approach study and is a sub-study of a parent research project which examines the role of psychological flexibility in recovery following concussion (Faulkner et al., 2021a). This research is supported by Proactive Rehabilitation Concussion services and the Health Research Council of New Zealand.

1. Participants and Procedure

A total of 169 participants were involved in this study. Recruitment occurred in the Wellington and Manawatu regions through Proactive Concussion services between March 2020 and September 2020. Recruitment criteria included participants being 18 years of age or over with a diagnosis of mTBI, who had been referred to concussion services. Definition of mTBI was that endorsed by ACC and is based on the World Health Organisation (WHO) Neurotrauma Task Force criteria (Menon et al., 2010). The exclusion criteria encompassed individuals who did not speak English fluently and who experienced prior neurological conditions, or severe unstable medical illnesses.

Patients referred to Proactive concussion services were provided information about the current research by a clinician who was working with the potential participant. These staff members were educated on the inclusion and exclusion criteria of this study. Consent was attained from interested and eligible participants to be contacted by a member of the research team for further communication. Within 30-days of entry to the concussion service, a researcher then contacted the potential participant directly and reiterated the information provided on the information sheet and formally enrolled the participant into the study. The participant was then sent the self-report measures electronically by a secure web-based platform (REDCAP). REDCAP is a software solution designed for rapid development and

deployment of electronic data to support clinical and translational research (Harris et al., 2009). The completion of the measures took approximately 30-45 minutes. Participants were able to take breaks when and if required.

2. Materials

A summary of the variables assessed in this study are presented in Table 1. These variables were categorised into two groups: predictor variables and outcome variables. Predictor variables were those that were analysed to have an influence on an mTBI outcome. The mTBI outcome variables were PCS and functional status.

Table 1

Predictor and Outcome Variables

Predictor Variables	Dependent Variables
Demographic and Clinical Characteristics	Post-concussion symptoms
Psychological status	Functional Status
PTSD Symptoms	
Fear Avoidance	
Psychological Flexibility	

3. Predictor Variables:

a. Clinical and Demographic Characteristics

Clinical and demographic data was attained through a self-report questionnaire sent to participants. Demographic variables included data on age, gender, ethnicity, level of

education, relationship status, substance use, pre-injury employment status, medical, concussion and mental health history. Clinical characteristics were also ascertained via the same self-report questionnaire. The clinical characteristics collected included information on time since injury, mechanism of injury, and other injuries sustained. Clinical records were assessed with ethical consent.

b. Psychological Status

Psychological status was assessed by the Depression, Anxiety and Stress Scale-21 (DASS-21) (Lovibond & Lovibond, 1995). The DASS-21 is a 21 item self-report questionnaire designed to measure the severity of symptoms common in depression, stress and anxiety (Gloster et al., 2008). The DASS-21 is comprised of three scales designed to measure symptomatology associated with depression, anxiety and stress in the past week. Each scale is comprised of 7 items (Gloster et al., 2008). The DASS-21 utilises a 4-point Likert scale with scores of 0- “never”, 1- “sometimes”, 2- “often”, and 3- “always”. The total scores fall within five categories: normal, mild, moderate, severe and extremely severe (Lovibond &Lovibond, 1995). The higher the scores the greater the severity of depression, anxiety and stress- symptoms. The DASS-21 has been widely used to assess psychological distress and has been observed to be a good psychometric measure with a Cronbach’s alpha of 0.73-0.81. In addition, the DASS-21 has been validated within the TBI population (Dahm et al., 2013).

c. Post-Traumatic Stress Disorder Symptoms

PTSS were assessed using the Impact of Events Scale-Revised (IES-R) (Weiss & Marmar, 1996). This tool is a 22 item self-report measure of psychological distress in response to a specific traumatic event. Items are rated on a 5-point Likert scale ranging from 0- "not at all" to 4- "extremely". The IES-R yields a total score from 0 to 88. The score is

interpreted as follows, 24 or more, indicates that PTSD is a clinical concern (Weiss, 2007). Individuals with scores this high who do not have full PTSD will have partial PTSD or at least some of the symptoms (Weiss, 2007). Scores of 33 and above represent the best cut off for a probable diagnosis of PTSD (Weiss, 2007). Lastly, scores of 37 or more, are high enough to suppress your immune system's functioning (even 10 years after an impact event) and therefore are of serious concern (Weiss, 2007). The IES-R includes three subscales which describe the three major symptom clusters of posttraumatic stress such as intrusion, avoidance, and hyperarousal. The IES-R is not a diagnostic tool for PTSD, rather an appropriate instrument to measure the subjective response to a specific traumatic event (Mathias & Coats, 1999). The IES-R has been widely used in TBI research (Mathias & Coats, 1999) and has sound validity and reliability (Mathias & Coats, 1999). A study by Bryant et al. (2003), assessed treating methods for individuals who experienced ASD after sustaining a mTBI. Bryant et al. (2003) used the IES-R and found that this measure at the six-month follow-up evaluation, indicated significant scores on the intrusions and avoidance subscales. Additionally, this study indicated that individuals with ASD often developed PTSD at the six-months follow-up (Bryant et al., 2003), suggesting that ASD is a significant predictor for the development of PTSD, supporting the IES-R tool as a valid measure of PTSS.

d. Psychological Flexibility

Psychological flexibility was measured using the Acceptance and Action Questionnaire-Acquired Brain Injury (AAQ-ABI) (Reactive Avoidance (RA)). The AAQ-ABI (RA) is a 9-item questionnaire covering questions which address psychological flexibility associated with reactions regarding having a brain injury (Sylvester, 2011; Whiting et al., 2015). The AAQ-ABI contains 15 items (Sylvester, 2011) and has a three-factor structure (factor 1 (9 items) = reactive avoidance; factor 2 (2 items) = denial; factor 3 (2 items) = active acceptance). According to Whiting et al. (2015), factors 2 and 3 demonstrate

poor psychometric properties. Consequently, the present study used the AAQ-ABI (RA) which uses a 5-point Likert scale (0- “never true” to 4- “always true”) with scores ranging from 0 to 36 (Sylvester et al., 2011). Higher scores are indicative of higher psychological inflexibility associated with an ABI. The AAQ-ABI (RA) has been developed and validated in an undifferentiated sample of ABI with a Cronbach’s alpha of 0.89 (Whiting et al., 2015). There were mild modifications in the current study. Terminology such as ‘brain injury’ was replaced with ‘concussion’. Faulkner and colleagues (2021b) examined the psychometric properties of the AAQ-ABI within a mTBI sample of 112 participants. The AAQ-ABI was tested using exploratory factor and Rasch analysis to assess the dimensionality, facture structure and differential item functioning (Faulkner et al., 2021b). The AAQ-ABI (RA) was found to have strong internal consistency (Cronbach’s $\alpha = 0.87$) which was consistent with previous findings. Overall, the AAQ-ABI (RA) appears to be a psychometrically sound and valid tool for measuring psychological flexibility in mTBI populations (Faulkner et al., 2021b).

e. Fear Avoidance

Fear avoidance was measured using the Fear Avoidance Behaviour after Traumatic Brain Injury Questionnaire (FAB-TBI). This tool is a 16-item measure which is drawn from well-established fear avoidance scales, predominantly from the chronic pain literature (Silverberg et al., 2018). The FAB-TBI is a self-report measure which uses a 4-point Likert scale asking participants to indicate how much they agree with each statement as applied over the previous month (Silverberg et al., 2018; Snell et al., 2019). To assess the validity and reliability of the FAB-TBI an exploratory factor analysis and Rasch analysis was conducted to evaluate the dimensionality, factor structure and differential item functioning (Snell et al., 2019). Exploratory factor analysis indicated two distinct factors: activity avoidance and cogniphobia. Activity avoidance is the avoidance of physical activity to prevent pain,

otherwise known as kinesiophobia (Silverberg et al., 2017). Whereas cogniphobia is the fear and avoidance of cognitive exertion, which is believed to precipitate or exacerbate headaches (Silverberg et al., 2017). The Rasch model was adequate, with one misfitting item. Overall, the FAB-TBI scale was found to have strong internal consistency (Cronbach's $\alpha = 0.9$) respectively (Snell et al., 2019). In the current study, raw scores were converted to interval scores as per the recommendations of Snell et al., (2019).

4. Dependent Variables:

a. Post-Concussion Symptoms

PCS were assessed by the Rivermead Post-Concussion Symptom Questionnaire (RPQ) (King et al., 1995). This psychometric tool is a 16 item self-report questionnaire that assesses symptoms commonly experienced following mTBI. These include somatic symptoms, such as headaches, dizziness, nausea, vomiting, noise and light sensitivity, sleep disturbance and double vision (Potter et al., 2006). Cognitive symptoms, such as forgetfulness, poor memory, poor concentration and processing speed (Potter et al., 2006). Lastly emotional symptoms, include, being irritable, easily angered, feeling depressed or tearful, frustrated or impatient (Potter et al., 2006). The RPQ uses a Likert scale, which requires participants to rate the presence and problem status on a scale of 0-4, (0 - “not experienced at all”, 1- “no more of a problem than before injury”, 2- “a mild problem” 3- “a moderate problem”, 4- “a severe problem”). The reliability and validity of the RPQ is strong with a Cronbach’s alpha of 0.90 respectively (King et al., 1995) and is extensively used to assess the severity of PCS (Eyres et al., 2005). As per the recommendations of King et al. (1995), items rated as 1- (“no more of a problem than before injury”) were converted to 0- (“not experienced at all”).

b. Functional Status

To assess functional status the 12-item WHO Disability Assessment Schedule (WHODAS 2.0) was used. The WHODAS 2.0 is a questionnaire which assesses difficulties due to health conditions. These health conditions include diseases, illnesses, or other health problems that are either short or long lasting, such as, mental or emotional problems, injuries, and alcohol or drug abuse (Üstün et al., 2010; Federici et al., 2016). The WHODAS 2.0 has been used within TBI populations and has been validated in the TBI literature (Tarvonen-Schröder et al., 2018; Snell et al., 2020). Participants were asked to respond to the level of difficulty they have been experiencing over the past 30 days in relation to all their health problem for each of the 12 items. This questionnaire is measured on a Likert scale, with options such as, 0- "none", 1- "mild", 2- "moderate", 3- "severe", and 4- "extreme/cannot do". Higher scores indicate greater disability. According to Snell et al. (2020) the 12-item WHODAS 2.0 demonstrated high internal consistency in mTBI with a Cronbach's alpha of 0.92 respectively. Snell et al. (2020) recommended to convert the ordinal scores on the WHODAS 2.0 into interval scores using their conversion table, thus improving the psychometric properties of the measure. These recommendations were followed in the current study.

5. Ethics

Ethics approval has been granted by the Auckland University of Technology Ethics Committee on 19 February 2020. AUTEC Reference number 20/32. Data has been collected and stored via a password protected database, specifically REDCAP online (Harris et al., 2009) research tool. The confidentiality of all participants has been protected by de-identifying participant information. Participants were classified using a unique participant ID number. Participants contact details were initially stored on a password protected device, being deleted following contact. Access to study data was limited to key personnel. All data will be stored for six years and then destroyed.

Participants were offered a $20 voucher as a token of appreciation for taking the time to be a part of the study and were thanked for their efforts. This project is funded by the Health Research Council – Clinical Research Fellowship (Foxley Fellowship).

6. Data Analysis:

For all statistical analyses Statistical Package for Social Sciences (SPSS) Version 25 was used with a significant level set at .05 (p <.05) to signify statistical significance. A power analysis using the G*power software (Faulkner et al., 2021b) was used to ensure adequate sample size for the regression analysis. Assuming a medium effect size (f^2) of 0.15, an alpha of 0.80, and a maximum of 11 predictors, power analysis suggested a minimum sample of 127 participants. Descriptive analysis and Pearson's product correlations were conducted to broadly characterise the sample (age, gender, ethnicity, education, employment and relationship status, medical and mental health history, and injury characteristics). Descriptive statistics are reported as numbers and percentages for categorical variables, means and standard deviations for continuous variables.

Descriptive analysis was used to explore the associations and to broadly characterise the dependent and predictor variables. To address our first aim, which was to explore the impact of PTSS on mTBI, Pearson's product correlations were first conducted to explore the relationship between PTSS and PCS and functional status. Correlations were interpreted as very weak (0.00-0.19), weak (0.20-0.39), moderate (0.40-0.59), strong (0.60-0.79), or very strong (0.80-1.00) (Evans, 1996). Multiple linear regression was then used. Specially, two regression analyses were computed to determine the unique contribution that PTSS made to PCS and functional status at clinic intake. Variables known to exert an influence on mTBI outcomes were entered into our multiple linear regression model analyses (Heinze et al., 2018). This included age (Karr et al., 2020; Faulkner et al., 2020), gender (Bazarian et al.,

2010; Faulkner et al., 2020), medical history (Ponsford et al., 2012; Faulkner et al., 2020), other injury sustained (Cnossen et al., 2018; Faulkner et al., 2020), concussion history (Theadom et al., 2016; Faulkner et al., 2020), and mental health history (Faulkner et al., 2020). In addition, given the influence that acute psychological distress has on mTBI outcomes (Silverberg et al., 2015) psychological functioning (depression, anxiety and stress) was also added into the regression model. The selected predictor variables were entered into a multiple regression model to identify the factors that made a significant contribution to RPQ or WHODAS 2.0.

To address our second aim, a similar process was used. Pearson's product correlations was conducted to explore the relationship between PTSS and psychological flexibility and fear avoidance. Multiple linear regression was also used to explore the contribution of these psychological mechanisms on PTSS in mTBI. Specifically, a regression analysis was computed with PTSS as the dependent variable, and fear avoidance and psychological flexibility entered into the model. Variables known to exert an influence on PTSS were also added into the model. This included age, education, relationship status and prior mental health history (Li et al., 2020; Elliot et al., 2021; Pall, 2001; Bryant & Harvey, 1998; Sadock et al., 2015). Depression was also entered into these models given previous findings of the high association between negative affect and measures of psychological flexibility (Kashdan et al., 2020). The selected predictor variables were entered into a multiple regression model to identify the factors that made a significant contribution to PTSS.

The assumptions for regression analysis were met for each analysis including checks for homoscedasticity, linearity, independence, and normality of residuals (Field, 2013). Correlations between each of the predictors (supplementary Table 1) were checked and if there was a high correlation (> 0.7) between the predictors, then only the predictor with the most significant contribution to the model was included.

In accordance with the third aim, a series of mediation analyses were conducted using PROCESS for SPSS (Hayes, 2012) to evaluate the indirect effects of psychological mechanisms (psychological flexibility and fear avoidance) on the relationship between predictors (PTSS) and dependent variables (PCS and functional status). Firstly, the relationships were estimated; the individual effect of each dependent variable on each mediator (i.e., PTSS, AAQ-ABI(RA); path A), the effect of each mediator on the predictor variables (i.e., AAQ-ABI(RA), PCS; path B), and the indirect effect of the dependent variables through each of the individual mediators (path A x B). Secondly, the relationships were compared to the direct effect (path C'; the effect of the dependent variable on the predictor variable minus each mediator) and the total effect (path C; the effect of the dependent variable on the predictor variable plus each mediator). Thirdly, the magnitude of the mediation effects was assessed, the magnitude of all mediation effects (paths A x B) by the standardised beta coefficients. Models were analysed, with each predictor and dependent variable, and two mediators (PROCESS model #4). The reliability of the sample mediation effects was assessed via the percentile (nonparametric) 95% confidence interval (CI) generated by a bootstrapping procedure with a resample rate of 5,000 to avoid inflation of type 1 error rate (Preacher & Hayes, 2008; Fritz et al., 2012). Bootstrapping is a computational nonparametric resampling technique that enables population characteristics to be estimated from the existing sample (Mooney et al., 1993). We report variance in PCS and functional status that is explained by each mediation model (overall R2).

Chapter Four: Results

Vital information emerged from this current study. The analyses were conducted in six stages. First, descriptive data was generated to provide information on the characteristics of the sample. Second, correlational analysis was conducted to examine the strength and direction of the relationships between PTSS and outcome variables. Third, the multiple linear regression model was used to explore the relationships between PTSS and outcomes to examine whether other variables implicated this relationship. Forth, correlational analysis was conducted to ascertain the degree and direction of relationships between individuals experiencing psychological flexibility, fear avoidance and PTSS. Fifth, multiple linear regression was used to again explore the possibility of other variables contributing to outcomes within this association. Lastly, multiple mediation was used to assess the role of psychological flexibility and fear avoidance as underlying psychological mechanisms that contribute to the relationship between PTSS and mTBI outcomes.

1. Participant Characteristics

Table 2 represents the demographic and clinical characteristics of the 169 participants in this study. 65.7% of participants were female and 46.2% of participants were within the age group of 18-29. Participants were predominantly NZ European 63.8% and 63.9% obtained a tertiary/university qualification. 68.0% of participants indicated that they were in a relationship. Pre-injury employment indicated that 84% of participants were working, whereas post-injury employment decreased to 68%. Falls were the most common mechanism of injury 40.2% and 57.4% participants sustained a comorbid injury. 63.3% of participants had no previous medical history. Mental health history did not indicate a big discrepancy, with 50.9% having experienced no mental health and 49.1% of participants having had experienced some sort of mental health prior to injury. Additionally,

concussion history was also attained with 56.8% of participants having had no previous mTBI. Lastly, time since injury indicated that 68% of participants experienced an mTBI less than eight weeks upon first intake.

Table 2

Demographic and Clinical Characteristics of the Sample (n=169)

Demographic Characteristic	**Frequency (%)**
Gender	
Female	111 (65.7)
Male	58 (34.3)
Age Groups	
18-29 years	78 (46.2)
30-44 years	46 (27.2)
45+ years	45 (26.6)
Ethnicity	
NZ European	108 (63.8)
Other	40 (23.8)
Māori	21 (12.4)
Education	
University/tertiary	108 (63.9)
High school and less	61 (36.1)
Relationship status	
In a relationship	115 (68.0)
Not in a relationship	54 (32.0)
Pre-injury Employment	
In paid Employed	142 (84)
Not in paid employment	27 (16)
Post-injury employment	
In paid Employed	115 (68)
Not in paid employment	54 (32.0)
Clinical Characteristics	

Mechanism of injury	
Fall	68 (40.2)
Hit by object	50 (29.6)
Transport	19 (11.2)
Other	18 (10.7)
Assault	14 (8.3)
Other injuries sustained	
Yes	97 (57.4)
No	72 (42.6)
Medical history	
No	107 (63.3)
Yes	52 (30.8)
Missing	10 (5.9)
Mental health history	
No	86 (50.9)
Yes	83 (49.1)
Concussion history	
No	96 (56.8)
Yes	73 (43.2)
Time since injury	
Less than 8 weeks	115 (68)
8 weeks and greater	54 (32)

2. PTSS and mTBI Outcomes

a. Dependent and Outcome Measures

The sample mean for the IES-R Total scores was (M = 25.77, SD 20.35), indicating that many individuals exhibited PTSS. The RPQ sample mean (M = 28.72, SD = 14.56) revealed that several individuals experienced some PCS. Scores from the DASS-21 included depression (M = 6.58, SD = 6.08, anxiety (M = 5.66, SD = 4.80) and

stress (M = 8.85, SD 5.11), all of which indicated mild to moderate levels in the sample. The sample mean for the WHODAS 2.0 was (M = 18.59, SD = 4.80), this indicated that individuals did not experience severe disability. Refer to Table 3 for more data.

Table 3

Descriptive Statistics, Dependent and Outcome Measures

	Minimum	Maximum	Mean	Std Deviation
RPQ	0.00	64.00	28.7160	14.55866
DASS-21 Stress	0.00	21.00	8.8521	5.11377
DASS-21 Anxiety	0.00	21.00	5.6627	4.80189
DASS-21 Depression	0.00	24.00	6.5858	6.08130
WHODAS 2.0	0.00	36.97	18.5974	4.79677
IES-R Total	0.00	85.00	25.7751	20.35978

RPQ = Rivermead Post-Concussion Symptoms Questionnaire; DASS-21 = Depression Anxiety Stress Scale-21; WHODAS 2.0 = World Health Organisation Disability Assessment Schedule 2.0. IES-R Total = Impact of Events Scale-Revised (IES-R).

3. PTSS and Outcome Variable Correlations

The relationships between PTSS and outcome variables were explored using Pearson's product correlations. Total PTSD symptoms was found to be significantly associated with all outcome variables. Specifically, significantly large positive correlations were found between PTSD total symptoms and RPQ (r = .64, p = <.001) and PTSD total symptoms and WHODAS 2.0 (r = .65, p = <.001). Refer to Table 4 for further data.

Table 4

Pearson's Product Correlations for Predictor and Outcome Measures

	RPQ	Stress (DASS-21)	Anxiety (DASS-21)	Depression (DASS-21)	WHODAS 2.0	IES-R Total
RPQ	1	.678 **	.570**	.516**	.636**	.644**
Stress (DASS-21)	.678**	1	.719**	.699**	.574**	.636**
Anxiety (DASS-21)	.570**	.719**	1	.699**	.586**	.662**
Depression (DASS-21)	.516**	.699**	.622**	1	.578**	.605**
WHODAS 2.0	.636**	.574**	.586**	.578**	1	.649**
IES-R Total	.644**	.636**	.662**	.605**	.649**	1

RPQ = Rivermead Post-Concussion Symptoms Questionnaire; DASS-21 = Depression Anxiety Stress Scale-21; WHODAS 2.0 = World Health Organisation Disability Assessment Schedule 2.0. IES-R Total = Impact of Events Scale-Revised (IES-R).

*** Correlation is significant at the 0.01 level (2-tailed)*

4. Multiple Linear Regression Model

a. PTSS and Post-Concussion Symptoms

To further explore the relationships between PTSS and PCS a multiple linear regression was conducted. The model, with total PTSD symptoms, psychological distress, age, gender, medical history, concussion history, mental health history and other injuries sustained, were significantly associated with PCS ($F(10,148) = 17.88$, $p < .001$, $R^2 = .58$). Total PTSD symptoms were found to make a significant and unique contribution to PCS ($\beta =$

0.25, $p < .001$). In addition, stress and medical history also made a significant and unique contribution to PCS ($\beta = -1.31$, $p = <.01$; $\beta = -4.90$, $p < .001$) respectively. Refer to Table 5 for β coefficient (β), standard error of measurement (SE) and significance (p) of the regression model.

Table 5

Coefficients for Multiple Linear Regression for Predictor Variables and Post-Concussion Symptoms at Time Point One

Variable	*B*	SE	*P*
Age	-0.04	0.07	.55
Gender	1.17	1.72	.50
Other injury	-0.65	1.79	.72
Concussion history	1.31	1.72	.45
Medical history	-4.90	1.81	.01*
Mental health history	0.90	1.70	.60
DASS-21 Stress	1.31	0.26	<.01**
DASS-21 Anxiety	0.10	0.26	.71
DASS-21 Depression	-0.15	0.21	.47
IES-R (Total)	0.25	0.06	<.01**

a Dependent Variable: Post-concussion symptoms (RPQ). RPQ = Rivermead Post-Concussion Symptoms Questionnaire; DASS-21 = Depression Anxiety Stress Scale-21; IES-R Total = Impact of Events Scale-Revised (IES-R).

**Significance p = <.05, ** p= <.01*

b. PTSS and Functional Status

The relationships between PTSS and functional status was investigated using a multiple linear regression model. The model, with total PTSD symptoms, psychological distress, age, gender, medical history, concussion history, mental health history and other

injuries sustained, was meaningfully associated with PCS at time point one ($F(10,148) = 16.25$, $p < .000$, $R^2 = .52$). Total PTSD symptoms was found to make a significant and unique contribution to functional status (β .077, $p < .000$). Additionally, gender (β 1.234, $p < 0.35$) and depression (β .171, $p < 0.16$) also contributed to functional status. Refer to Table 6 for β coefficient (β), standard error of measurement (SE) and significance (p) of the regression model.

Table 6

Coefficients for Multiple Linear Regression for Outcome Variables and Functional Status at Time Point One

Variable	*B*	SE	*P*
Age	.013	.230	0.587
Gender	1.234	.589	.038
Other injury	-.022	.613	.971
Concussion history	.578	.589	.328
Medical history	-.432	.619	.487
Mental health history	-.074	.584	.899
DASS-21 Stress	.100	.089	.263
DASS-21 Anxiety	.159	.089	.077
DASS-21 Depression	.171	.070	.016
IES-R (Total)	.077	.020	.000

a Outcome Variable: Functional Status WHODAS 2.0. WHODAS 2.0; World Health Organisation Disability Assessment Schedule 2.0. DASS-21 = Depression Anxiety Stress Scale-21; IES-R Total = Impact of Events Scale-Revised (IES-R).

**Significance p = <.05, ** p= <.00*

5. PTSS, Psychological Flexibility and Fear Avoidance

a. Psychological Flexibility and Fear Avoidance

The AAQ-ABI (RA) (M = 10.10, SD = 3.51) indicated that individuals experienced elevated levels of psychological inflexibility. FAB-TBI (M = 23.71, SD = 6.44) indicated that individuals experienced high levels of fear avoidance. Refer to Table 7 for further data.

Table 7

Descriptive Statistics, for Fear Avoidance and Psychological Flexibility

	Minimum	Maximum	Mean	Std Deviation
FAB-TBI	.00	48.00	23.72	6.44
AAQ-ABI (RA)	.00	22.44	10.09	3.51

FAB-TBI= Fear Avoidance Behaviour after Traumatic Brain Injury Questionnaire; AAQ-TBI (RA)= Acceptance and Action Questionnaire-Acquired Brain Injury (AAQ-ABI) Reactive Avoidance (RA).

6. PTSS and Psychological Mechanisms Correlations

The relationship between PTSS and psychological mechanisms were explored using Pearson's product correlations. Total PTSD symptoms was found to be significantly associated with both psychological flexibility and fear avoidance. The AAQ-ABI (RA) and IES-R were found to be moderately positively corelated (r = .57, p <.001). The FAB-TBI and IES-R were also found to be moderately positively correlated (r = .56, p <.001). Refer to Table 8 for further data.

Table 8

Pearson's Product Correlations for Predictor and Outcome Measures

	FAB-TBI	IES-R Total
AAQ-ABI (RA)	.606**	.571**
FAB-TBI		.566**

AAQ-TBI (RA)= Acceptance and Action Questionnaire-Acquired Brain Injury (AAQ-ABI) Reactive Avoidance (RA); FAB-TBI= Fear Avoidance Behaviour after Traumatic Brain Injury Questionnaire.

*** Correlation is significant at the 0.01 level (2-tailed)*

7. Multiple Linear Regression Model

a. PTSS and Psychological Flexibility

To further explore the relationship and the influence of psychological flexibility on PTSS, a multiple linear regression model was conducted. The model, with psychological flexibility, gender, mental health history, education status, relationship status and depression, was meaningfully associated PTSS ($F(6,162) = 21.72$, $p < .001$, $R^2 = .45$). Psychological flexibility was found to make a significant and unique contribution to PTSS ($\beta = 1.825$, $p < .001$). Additionally, education status and depression also made a significant and unique contribution to PTSS ($\beta = -6.97$, $p = <.001$; $\beta = 1.27$, $p < .001$) respectively. Refer to Table 9 for β coefficient (β), standard error of measurement (SE) and significance (p) of the regression model.

Table 9

Multiple Linear Regression Model of PTSD and Psychological Flexibility

Variable	*B*	SE	*P*
Gender	1.205	2.530	.635
Mental health history	.904	2.534	.722
Education Status	-6.975	2.528	.006**
Relationship Status	-.105	2.532	.967
DASS-21 Depression	1.266	.275	.000**
AAQ-ABI (RA)	1.825	2.461	.000**

a Dependent Variable: IES-R Total. IES Total = Impact of Events Scale-Revised (IES-R); DASS-21 = Depression Anxiety Stress Scale-21; AAQ-TBI (RA)= Acceptance and Action Questionnaire-Acquired Brain Injury (AAQ-ABI) Reactive Avoidance (RA).

**Significance p = <.05, ** p= <.00*

b. PTSS and Fear Avoidance

Additionally, the influence of fear avoidance on PTSS was investigated using a multiple linear regression. The model, with total PTSD symptoms, gender, mental health history, education status, relationship status and depression, was significantly associated with fear avoidance ($F(6,162) = 23.14$, $p < .001$, $R^2 = .46$). Fear avoidance was found to make a significant and unique contribution to PTSS ($\beta = .65$, $p < .001$). Education status and depression also made a significant and unique contribution to PTSS ($\beta = -5.70$, $p = <.024$; $\beta = 1.42$, $p < .001$) respectively. Refer to Table 10 for β coefficient (β), standard error of measurement (SE) and significance (p) of the regression model.

Table 10

Multiple Linear Regression Model of PTSD and Fear Avoidance

Variable	*B*	SE	*P*
Gender	1.894	2.480	.446
Mental health history	-.356	2.483	.446
Education Status	-5.692	2.494	.024*
Relationship Status	-.428	2.494	.864
DASS-21 Depression	1.422	.240	.000**
FAB-TBI	.652	.143	.000**

a Dependent Variable: IES-R Total. IES-R IES Total = Impact of Events Scale-Revised (IES-R); DASS-21 = Depression Anxiety Stress Scale-21; FAB-TBI; Fear Avoidance Behaviour after Traumatic Brain Injury Questionnaire.

**Significance p = <.05, ** p= <.00*

8. The Mediation Effects of Psychological Flexibility and Fear Avoidance

The bootstrapped method (PROCESS) with $n = 5000$ bootstrap resamples and 95% bias corrected and accelerated confidence intervals was applied in a series of assessments to examine the indirect effects of psychological flexibility and fear avoidance on the relationship between PTSS and outcomes (PCS and functional status).

a. PTSS, Psychological Flexibility and Outcomes

As depicted in Figure 1, there was an indirect effect of PTSS on PCS through psychological flexibility (path A x B; β=0.14, 95% CI = 0.08-0.21, p <.001). Specifically, both paths A (β=0.01, 95% CI = 0.08-0.12, p <.001) and B (β=1.38, 95% CI = 0.82-1.93, p <.001) were significant. The total effect of PTSS on PCS was significant (path C; β=0.46, 95% CI = 0.38-0.54, p <.001), as was the direct effect of PTSS on PCS after including psychological flexibility (path C' β=0.32, 95% CI = 0.23-.42, p <.001), indicating that the meditation was partial.

There was also an indirect effect of PTSS on functional status through psychological flexibility (path A x B; β=0.06, 95% CI = 0.03-0.09, p <.001) (see Figure 2). Specifically, both paths A (β=0.01, 95% CI = 0.08-0.12, p <.001) and B (β=0.57, 95% CI = 0.40-0.74, p <.001) were significant. The total effect of PTSS on functional status was significant (path C; β=0.15, 95% CI = 0.13-0.18, p <.001), as was the direct effect of PTSS on functional status after including psychological flexibility (path C' β=0.10, 95% CI = 0.07-0.13, p <.001), indicating that the meditation was partial.

Figure 1

The Mediation Effects of Psychological Flexibility on the Relationship Between PTSS and Post-Concussion Outcomes

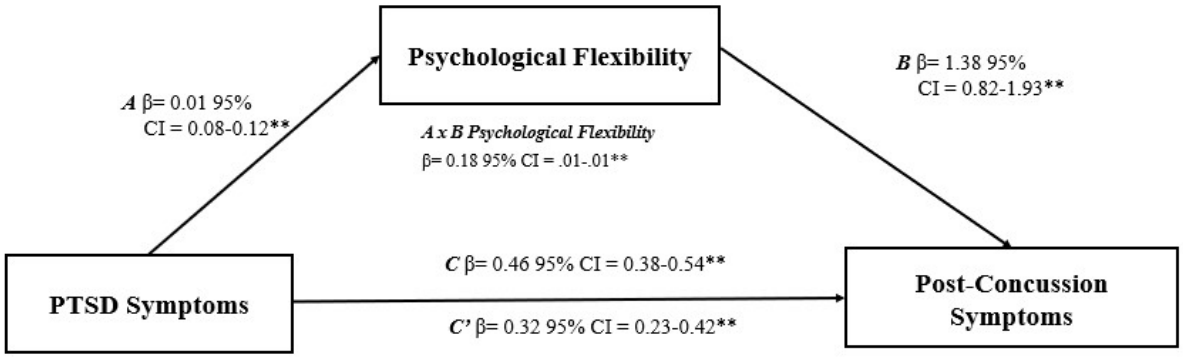
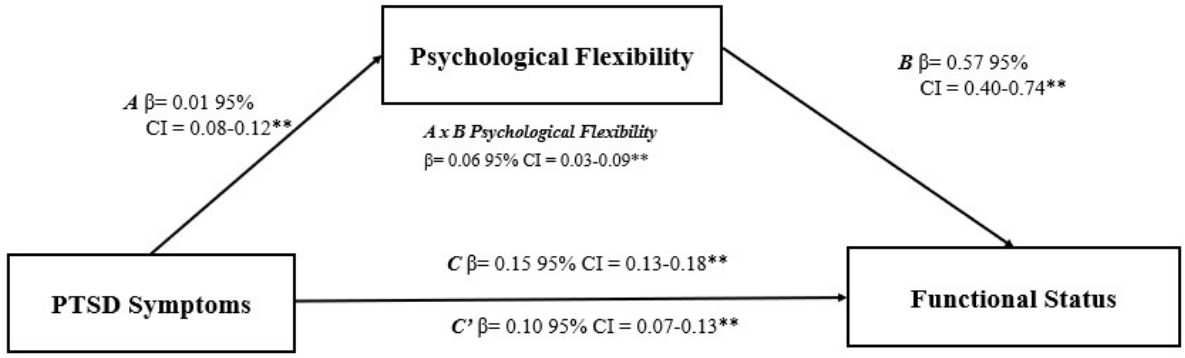


Figure 2

The Mediation Effects of Psychological Flexibility on the Relationship Between PTSS and Functional Status



b. PTSS, Fear Avoidance and Outcomes

There was an indirect effect of PTSS on PCS through fear avoidance (path A x B; β=0.07, 95% CI = 0.02-0.13, p <.001) (see Figure 3). Specifically, both paths A (β=0.18, 95% CI = 0.14- 0.22, p <.001) and B (β=0.41, 95% CI = 0.09-0.72, p =.012) were significant. The total effect of PTSS on PCS was significant (path C; β=0.46, 95% CI = 0.38-0.54, p <.001), as was the direct effect of PTSS on PCS after including fear avoidance (path C' β=0.39, 95% CI = 0.29-0.49, p <.001), indicating that the meditation was partial.

There was also an indirect effect of PTSS on functional status through fear avoidance (path A x B; β=0.06, 95% CI = 0.04-0.09, p <.001) (see Figure 4). Specifically, both paths A (β=0.18, 95% CI = 0.14-0.22, p <.001) and B (β=0.34, 95% CI = 0.25-0.44, p <.001) were significant. The total effect of PTSS on functional status was significant (path C; β=0.15, 95% CI = 0.13-0.18, p <.001), as was the direct effect of PTSS on functional status after including fear avoidance (path C' β=0.09, 95% CI = 0.06-0.12, p <.001), indicating that the meditation was partial.

Figure 3

The Mediation Effects of Fear Avoidance on the Relationship Between PTSS and PCS

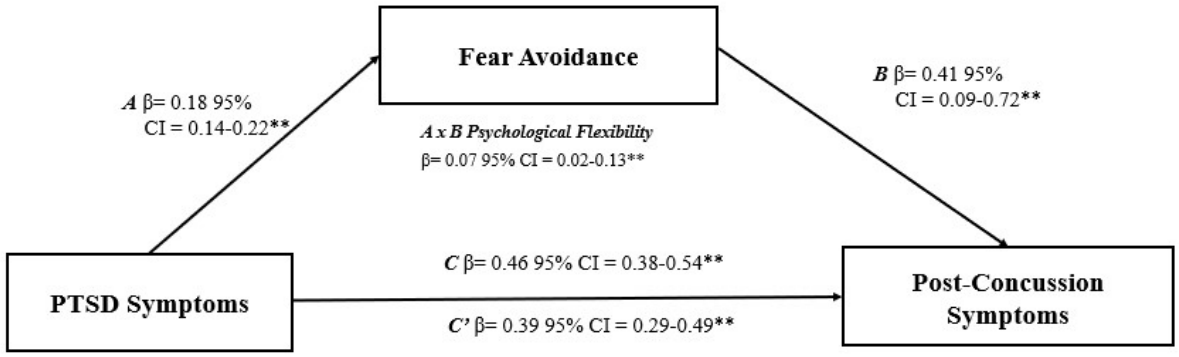
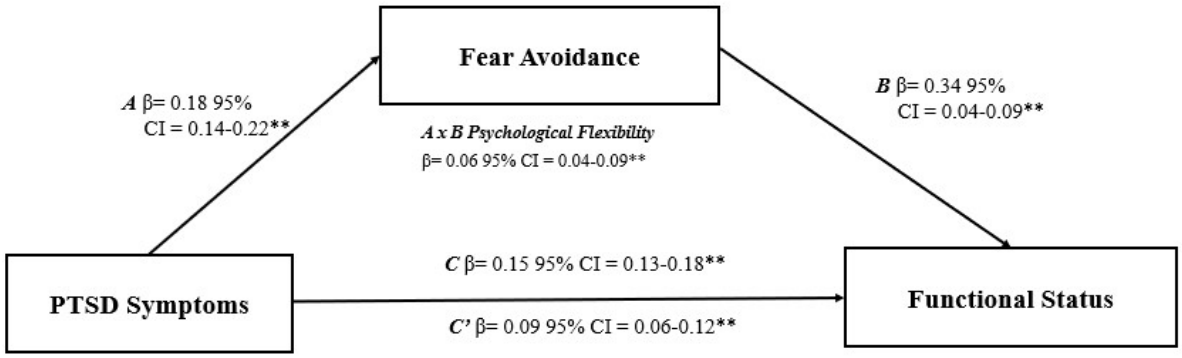


Figure 4

The Mediation Effects of Fear Avoidance on the Relationship Between PTSS and Functional Status



9. Multiple Meditation

Multiple meditation analysis was conducted to determine if psychological flexibility and fear avoidance explain the association between PTSS and outcomes when modelled simultaneously. In regard to PCS, as shown in Figure 5, PTSS was significantly associated with psychological flexibility and fear avoidance when entered together in path A. Figure 5 indicates that PTSS were significantly associated with both psychological flexibility and fear avoidance when entered together in path A (psychological flexibility; β=0.01, 95% CI = 0.08-0.12, p <.001; fear avoidance; β=0.18, 95% CI = 0.14-0.22, p <.001). Psychological flexibility was significantly associated with PCS (β=1.29, 95% CI = 0.68-0.19, p <.001) but

fear avoidance was not when entered together in path B (β=0.11, 95% CI = -0.22-0.44, *p* =.50). There was also an indirect effect of PTSS on PCS through psychological flexibility when fear avoidance was also entered (path A x B_1; β=0.18, 95% CI = 0.01-0.01, *p* <.001); however, the indirect effect of PTSS on PCS through fear avoidance when psychological flexibility was also entered was not significant (path A x B_2; β=0.02, 95% CI = -0.03-0.08, *p* =.58). The direct effect of PTSS on PCS remained significant (path C'; β=0.31, 95% CI = 0.21-0.41, *p* <.001), indicating that the multiple mediation effects were partial. Overall, the multiple meditation model has a whole explained 49% of the variance.

In regard to functional status shown in Figure 6, psychological flexibility and fear avoidance were significantly associated with functional status when entered together in path B (psychological flexibility; β=0.37, 95% CI = 0.19-0.54, *p* <.001; fear avoidance; β=0.26, 95% CI = 0.17-0.36, *p* <.001). There was also an indirect effect of PTSS on functional status through psychological flexibility when fear avoidance was also entered (path A x B_1; β=0.01, 95% CI = 0.01-0.01, *p* <.001); as well as a significant indirect effect of fear avoidance when psychological flexibility was entered (path A x B_2; β=0.02, 95% CI = 0.01-0.07, *p* <.001). There was also an indirect effect of PTSS on functional status through psychological flexibility when fear avoidance was also entered (path A x B; β=0.02, 95% CI = 0.01-0.07, *p* <.001). The direct effect of PTSS on functional status remained significant (path C'; β=0.16, 95% CI = 0.13-0.18, *p* <.001), indicating that the multiple mediation effects were partial. Overall, the multiple meditation model has a whole explained 42% of the variance.

Figure 5

The Relationship of Psychological Flexibility and Fear Avoidance Between PTSS and PCS

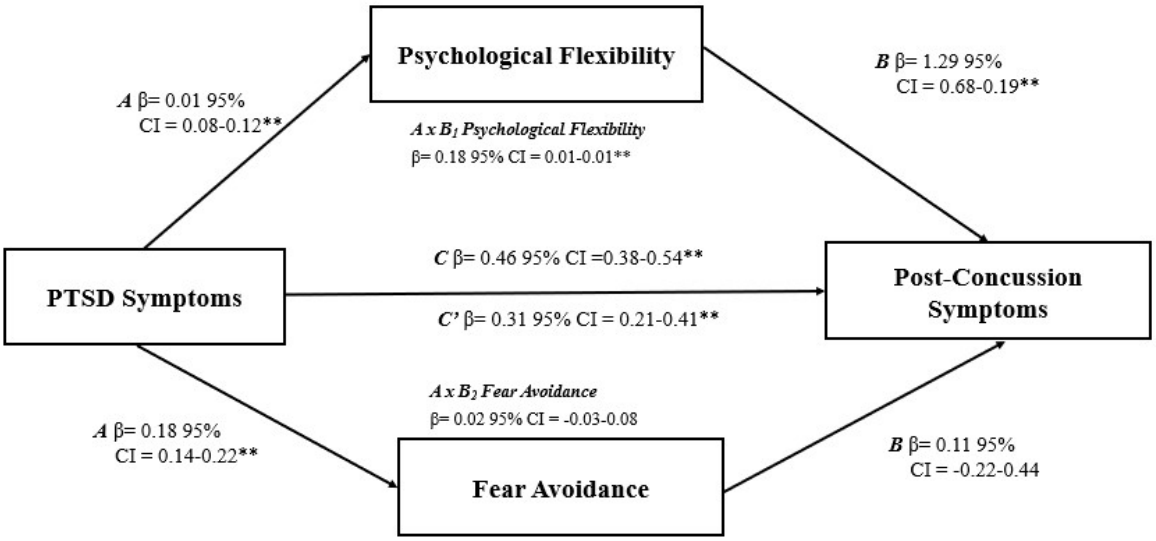
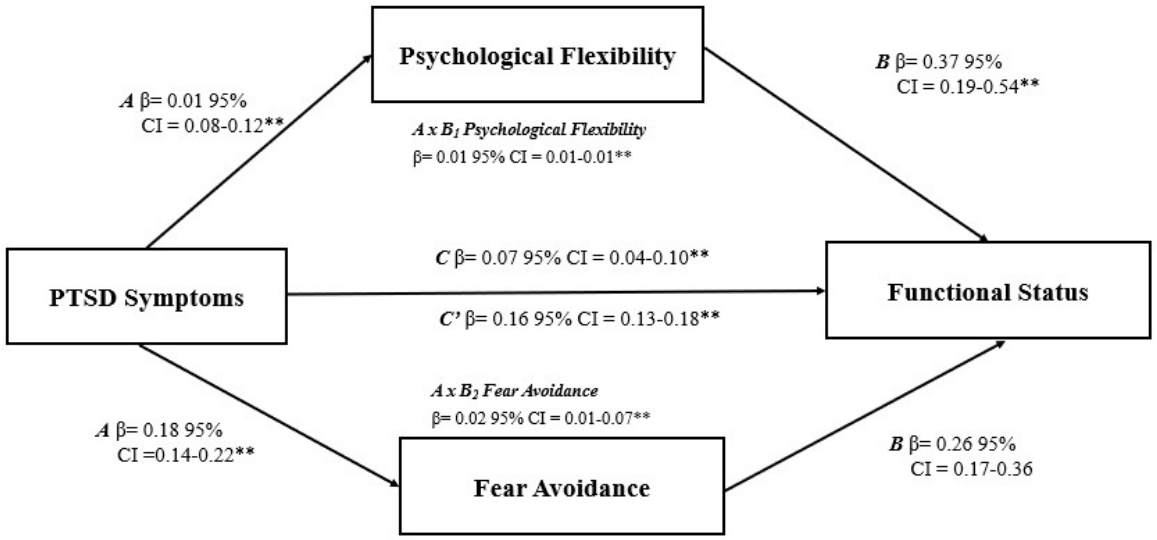


Figure 6

The Relationship of Psychological Flexibility and Fear Avoidance Between PTSS and Functional Status



Chapter Five: Discussion

The first objective of this study was to examine whether PTSS impacted mTBI recovery. The second goal, aimed to explore the role of psychological flexibility and fear avoidance on PTSS in mTBI. Thirdly, the study sought to explore the role of fear avoidance and psychological flexibility as underlying psychological mechanisms that contribute to the relationship between PTSS and mTBI outcomes. This study offers unique insight into this important yet limited literature, as it is the first study (known to the author) to assess the role of psychological mechanisms (psychological flexibility and fear avoidance) on PTSS in mTBI. Identifying underlying psychological mechanisms has the potential to inform more treatments and increase their effectiveness in mTBI recovery.

1. PTSS and Outcomes

The first aim of this study was to explore the impact PTSS had on mTBI outcomes. It was hypothesised that higher PTSS would be associated with higher PCS. In support of this hypothesis, a significant positive correlation was found between PTSS and PCS, as well as functional disability in mTBI. This indicates that as PTSS increase so to do PCS and functional disability. In addition to PTSS being associated with mTBI outcomes, a multiple linear regression model was used to assess for other variables which may have contributed to these outcomes. Several predictor variables known to influence mTBI outcomes were added to the regression models. It was hypothesised, that even when accounting for the impact of these confounding variables, PTSS would make a significant and unique contribution to mTBI outcomes. In support of this hypothesis, multiple linear regression analysis revealed that PTSS, as well as stress and medical history significantly contributed to PCS after mTBI. In addition, multiple linear regression analysis, also revealed that PTSS, as well as depression

and gender significantly contributed to functional disability after mTBI. These results will be discussed in more detail in the following section.

a. Post-Concussion Symptoms and PTSS

Previous research has found that PTSS are strongly associated with PCS (Klimova et al., 2019; Brenner et al., 2010; Aaes et al., 2018; Van Praag et al., 2019; Avallone et al., 2019). However, at present much research has focused primarily on military conflict situations/populations (Van Praag et al., 2019). For example, a recent study by Aase et al. (2018) examined 90 veterans, with the objective of understanding PTSD in the context of mTBI more clearly. The results indicated that veterans with comorbid mTBI and PTSD reported significantly higher PCS across domains, in addition to experiencing greater pain intensity and maladaptive coping (Aase et al., 2018). The implications of these findings suggest that the combination of mTBI and PTSD contributes to PCS, pain intolerance and unhelpful coping mechanisms and thus, may be of clinical importance.

Another cross-sectional study by Brenner et al. (2010) investigated the contribution of mTBI and/or PTSD to the endorsement of PCS during Post Deployment Health Assessment. The objective of the study was to determine whether a combination of mTBI and PTSD was more strongly associated with PCS than either condition alone. The soldiers with mTBI and PTSD (alone), reported PCS with specific symptoms such as headaches, dizziness, memory and balance problems, and irritability (Brenner et al., 2010). In contrast, the results of soldiers with a combination of mTBI and PTSD was associated with the highest prevalence of PCS (Brenner et al., 2010). In fact, results found that the combination of mTBI and PTSD predicted PCS, then either condition alone. These results support the importance of continued screening for both conditions with the aim of early identification and intervention (Brenner et al., 2010).

The predominantly military focused narrative in mTBI, PTSD and PCS research indicates that there is a significant overlap between PTSS and PCS. However, these findings cannot be generalisable to the wider population due to the uniqueness of the military population. Haarbauer-Krupa et al. (2017) noted that there is less awareness of PTSD and its implications on civilian mTBI. Consequently, Haarbauer-Krupa and colleagues (2017) examined the incidence and factors associated with PTSD at six-months post-injury in a civilian ED population. The study used measures from the National Institute of Neurological Disorders and Stroke TBI Common Data Elements Outcome Battery. 280 participants with mTBI from the Transforming Research and Clinical Knowledge in Traumatic Brain Injury Pilot study were analysed. PTSS were screened using the PTSD Checklist-Civilian Version. Descriptive measures were summarised and predictors for PTSD were examined using logistic regression. The results indicated that PTSS were significantly associated with concurrent functional disability, PCS, decreased satisfaction with life and decreased performance in visual processing and mental flexibility (Haarbauer-Krupa et al., 2017). These findings are consistent with the current study's findings and highlight the importance of screening for PTSS among the general population.

It is evident that there is a relationship between PTSS and PCS. There are multiple explanations for this association. Firstly, this relationship can be explained in reference to the biopsychosocial model. For example, pre-injury issues such as gender, previous mTBI, physical, mental and social factors (Ponsford et al., 2019; Rickards et al., 2020; Polinder et al., 2018; Eisenberg et al., 2013) strongly affect overlapping symptoms (depression, anxiety, PTSD) (Polinder et al., 2018) and post-injury factors (maladaptive beliefs, coping, perceived burden/stress) (Snell et al., 2015; Maestas et al., 2014). Furthermore, injury characteristics such as the context of the sustained mTBI and severity in addition to post-injury factors and overlapping symptoms directly contribute to PCS (i.e., somatic, emotional, behavioural and

cognitive) and therefore outcomes (Polinder et al., 2018; Snell et al., 2015; Maestas et al., 2014). To further illustrate this example, the results found by Haarbauer-Krupa et al. (2017) will be discussed. The study used multi-variable regression, that indicated that injury mechanism such as assault, prior psychiatric history (pre-injury factors) and level of education remained significant contributors to the development of PTSS post-mTBI. The study discovered that those who screened positive for PTSD had concurrent functional disability (decreased performance in visual processing and mental flexibility), PCS, psychiatric symptomologies and a decreased satisfaction with life (Haarbauer-Krupa et al., 2017). Consequently, whether in a military population or not, there are several constructs involved in the relationship between PTSS and PCS which exist in both civil and military contexts. These results suggest that screening for the presence of PTSS after mTBI is important as their presence will impact outcomes.

However, screening for the presence of PTSS when PCS is present, may introduce difficulties due to the non-specificity of PCS and how they overlap with PTSD. For example, the definitions of PCS vary and generally overlap with symptoms of PTSD. The International Classification of Diseases (ICD-10) (Lagacé-Legendre et al., 2021), specifies that PCS is defined by headaches, dizziness, general malaise, fatigue, noise intolerance, irritability, emotional lability, depression, anxiety, difficulty with concentration and memory, sleep disturbances, reduced tolerance to alcohol and a preoccupation with these symptoms, including a fear of permanent brain damage. Whereas the DSM-IV (APA, 2013) defines PCS as fatigue, sleep disturbance, headaches, dizziness, apathy, irritability, depression or anxiety and changes in personality. Evidently, these descriptions clearly overlap with symptoms of PTSD. This symptom overlap, thus causes issues with differential diagnosis, and increases the risk of potential misdiagnoses (Huguenard et al., 2020). Differentiating between PTSD

and PCS, especially in individuals diagnosed with both requires care (Lew et al., 2009) and is critical for the treatment and determination of disability (Santhanam et al., 2019).

Furthermore, as previously discussed, there is high comorbidity rate between mTBI and PTSD in both military and general populations (Sloley, 2020; Van Praag et al., 2019; Wolf et al., 2020). As such, experiencing PCS and PTSS simultaneously is common. According to Vanerploeg et al., (2009) PTSD and mTBI feed and reinforce each other. This overlap causes an exacerbation of existing symptoms and the development of other mental health disorders (Huguenard et al., 2020). In fact, if an individual experiences high levels of PTSS, the risk increases for developing comorbid mental disorders such as depression and anxiety. Psychological difficulties in turn increase the risk of developing PCS and affect cognitive functioning (O'Connor & Drebing, 2011). Implicated cognitive functioning thereby significantly impacts an individual's functional status.

Lastly, another possible explanation for why these constructs overlap includes the biological overlay in brain structures. Research has found that PTSD is associated with alterations in the hypothalamic-pituitary-adrenal (HPA) axis (Dunlop & Wong, 2019), which is strongly involved with varying degrees of mood disorders and functional illnesses. Similarly, mTBI are often sustained in the frontal regions of the brain releasing a cascade of neurotransmitters, causing secondary injury, central sensitisation, and alterations of the HPA axis (Patterson, 2016), which again, have been found to increase risk for psychiatric disorders (Russel et al., 2018). Although both PTSD and mTBI are found to have abnormal neural connectivity, there is limited research to fully understand this overlap.

Overall, present and past research findings strongly infer that there is a significant association between PTSS and PCS. Although it is possible to examine PTSS and PCS

through various lenses and in differing populations (general and military), the predominant reasons for this association involve the context in which the injury was sustained, the biopsychosocial model used to understand the association, the varying definitions used to define PCS, the non-specificity of PTSS and PCS overlap, the high comorbidity of experiencing other mental health disorders which exacerbate PTSS and PCS and lastly, the similarities in the biological overlay in brain structures.

b. Functional Disability and PTSS

This study also found that PTSS was significantly associated with functional disability following mTBI. Numerous studies have supported this finding (Jellestad et al., 2021; Veling et al., 2013; Leserman et al., 2005; van der Vlegel et al., 2021; Stojanovic et al., 2016; Stika et al., 2021; Combs et al., 2015; Kellezi et al., 2017; Sterling et al., 2005). Previous research investigating the effects of PTSS on functional status revealed that individuals with PTSS reported poor perceived general health and had high disability scores compared to those without PTSD (Veling et al., 2013). Furthermore, the study revealed that hyperarousal was most strongly associated with disability out of the three PTSD symptom clusters (Veling et al., 2013). This finding is not surprising considering one of the key functions of PTSD is bodily hyperarousal, a result of the "here and now" response to an intrusive memory/thought of the traumatic event (Ehlers & Clark, 2000). This hyperarousal then has the capacity to increase sensations (i.e., pain) leading to fear avoidance behaviours (Ehlers & Clark, 2000).

According to Veling et al. (2013), individuals with PTSD were pointedly more emotionally impacted by their health problems than those without PTSD (85% versus 41%), experiencing problems in activities involving social contact (54% versus 16%) and in completing daily duties (54% versus 20%). Another study, by Jones et al. (2014) found that

whilst mTBI alone was a predictor for a range of psychological problems, it did not predict diminished well-being or functional impairment in military veterans. Comparatively, when mTBI and PTSD were comorbid, there was evidence of significant disability (Jones et al., 2014). This suggests that mTBI alone may not be as debilitating as when comorbid with PTSD. These finding highlight the importance of assessing individuals for PTSS, as PTSS among individuals with and without mTBI prove to significantly effect functional ability.

Given these findings it is not surprising that PTSS can significantly impact daily functioning. However, to date, research on the complexity of functional impairment in individuals with PTSD is limited (Jellestad et al., 2021). A recent study by Jellestad and colleagues (2021) conducted a systematic literature search including observational studies comparing functioning among individuals with or without PTSD. In total, the study included 34 studies, with 14206 participants. The results revealed that in contrast to individuals without PTSD, those with PTSD showed significant impairments with large to very large effect sizes in all domains of mobility, domestic life, general tasks and demands, self-care, interpersonal interactions (including relationships) and social interaction in community (Jellestad et al., 2021). These findings enforce how debilitating PTSS can be on most areas of daily functioning, therefore early detection and treatment of PTSD would mitigate functional deficits.

It is known that individuals with mTBI are at risk of PCS and PTSD (Bryant, 2011). However, the co-occurrence of these features in relation to health-related quality of life (HRQoL), health care utilisation and return to work has not been rigorously investigated. A study by van der Vlegel et al. (2021) investigated the association of mTBI and PTSS on functional disability. The study was part of the prospective multi-centre longitudinal observational Collaborative European NeuroTrauma Effectiveness Research in Traumatic Brain Injury (CENTER-TBI) with a total of 4509 participants. The results showed that severe

PCS and PTSS were associated with the lowest HRQoL (van der Vlegel et al., 2021). Furthermore, lower HRQoL was associated with higher use of rehabilitation care and lower return to work rates (van der Vlegel et al., 2021). Additionally, PCS and PTSS were highly correlated, thus participants with probable PTSD, scored higher on PCS (van der Vlegel et al., 2021). A possible explanation for this was that severe PCS and PTSS may overlap and intensify one another thereby, explaining why those participants with combined symptoms had the lowest HRQoL scores. The results reiterate the importance of PTSS and PCS in mTBI and how if combined, they tend to significantly affect functional status. Therefore, assessing for PTSS within this population appears to be imperative.

It is evident that there is a relationship between PTSS and functional disability. There are several explanations for this association. Firstly, this relationship can be clarified in reference to the biopsychosocial model. For example, pre-trauma factors such as a genetic predisposition to PTSD, childhood trauma, gender, personality traits and stress (Sadock et al., 2015) implicate post-trauma factors (social/family networks, neuropsychological performance) (Hasto et al., 2013; Combs et al., 2015) and overlapping symptoms (comorbid disorders i.e., anxiety, depression, substance abuse and emotional dysregulation) (Combs et al., 2015; Sareen, 2014; Spinhoven et al., 2014). Post-trauma factors in combination with overlapping symptoms affect outcomes (physical, emotional and cognitive health, quality of life, social and occupational functioning). In other words, a lack of social support, perceived burden/stress and maladaptive coping believes influence outcomes on functioning within the emotional, physical, and cognitive domains thus impacting quality of life and functioning. To further illustrate this example, a study by Leserman et al. (2005) found that PTSS increased bodily pain and poorer physical, and cognitive functioning among individuals who experienced trauma in comparison to those who did not.

Secondly, PTSD significantly affects neuropsychological functioning (Combs et al., 2015) which directly affects functional ability. Research has shown that PTSD is highly associated with impairments in memory, attention, and executive functioning on objective cognitive measures (Vasterling & Brailey, 2005; Vasterling et al., 2009). Brewin et al. (2007) conducted a meta-analysis and found a small to moderate association between PTSS and immediate and delayed verbal memory impairments. According to Johnsen and Asbjørnsen (2008) these memory impairments were seen in military and civilian populations. Furthermore, Combs et al. (2015) also noted that individuals with PTSD also experienced verbal memory impairments, concentration difficulties, poor executive functioning, and deficits with processing speed (Nelson et al., 2009). Difficulties in these areas can tremendously affect and individuals' sense of self, occupational and social functioning including increasing the risk of comorbid disorders such as depression, anxiety and substance abuse (Nelson et al., 2009) thus affecting recovery.

Thirdly, individuals who experience PTSS often experience comorbid disorders such as depression, anxiety and substance abuse (Sadock et al., 2015; Nelson et al., 2009; Sareen, 2014). Although different, these illnesses have a significant symptom overlap (Nelson et al., 2009; Barbano et al., 2019). Overlapping symptoms can intensify present symptoms and thereby cause more severe functional disability (Barbano et al., 2019; Sareen, 2014). Furthermore, experiencing symptom overlap can increase the risk of misdiagnosis therefore affecting efficacious recovery. Consequently, it is pivotal for clinicians to differentiate between symptoms and consider treatment options which target the overlapping symptoms.

Lastly, avoidance is another possible explanation of why PTSS affect functional status. Avoidance is a key feature of PTSD (Sadock et al., 2015). Many studies have documented that avoidance due to a fear of physical or psychological discomfort restricts an individual's ability to partake in daily activities (Snell et al., 2020; Wijenberg et al., 2020;

Greenberg et al., 2020) and has been found to increase functional disability in other chronic illnesses (Wijenberg et al., 2020; Cassetta et al., 2021; Snell et al., 2019; Wijenberg et al., 2021; Greenberg et al. 2020). Avoidance is associated with an individual experiencing increased levels of hyperarousal (common symptom of PTSD). Hyperarousal is defined as the inability to regulate emotions due to the automatic nervous system (fight or flight response) being continuously or very easily activated (Williamson et al., 2013). Symptoms of hyperarousal include hypervigilance (hyper-alertness towards body sensations, noises, smells), exaggerated startle responses, difficulty with sleep, memory, cognitive impairments with concentration, irritability, and avoidance (Williamson et al., 2013). Increased hyperarousal is associated to fear and avoidance behaviour which often leads to symptomologies being exacerbated (i.e., increased pain sensations) (Ehlers & Clark, 2000). For example, a study by Stojanovic et al. (2016) investigated the mechanism of pain levels of veterans who experienced both PTSD and mTBI. Stojanovic and colleagues (2016) postulated that PTSD and mTBI may mediate pain processing in these individuals and affect their subjective pain levels. This cross-sectional study examined 310 deployed service members and found that veterans with both current PTSD and mTBI reported the highest intensity levels in comparison to veterans without PTSD and mTBI (Stojanovic et al., 2016). Additionally, veterans with PTSD but no mTBI also reported experiences with pain. This finding suggests that comorbid PTSD and mTBI is associated with increased self-reported pain intensity, whereas mTBI alone was not associated with increased pain. Pain is significantly debilitating with cognitive and physical processes, consequently, it is no surprise that pain would considerably affect functional status, increase risk of comorbid disorders, exacerbate existing symptoms, and increase maladaptive coping behaviours (substance abuse, unhelpful thinking styles, illness perception).

The correlation between PTSS and functional status is undeniable. Both present and past research findings stipulate that the effects of PTSS on functional status are profound, both physically and psychologically. Overall, there are several reasons for this relationship. The biopsychosocial model infers that PTSS affects functional disability for a myriad of reasons, which include personality traits, overlapping symptoms, support networks all of which affect the severity of functional outcomes. Neuropsychological abnormalities present in PTSS increase impairment in cognitive abilities and therefore impact an individual's sense of self. PTSD is also often associated with comorbid disorders, which can feed and reinforce existing symptoms, thus affecting functional status. Lastly the fear of experiencing unwanted thoughts or sensations leads to fear avoidant behaviours, which significantly impact an individual's functional status. These factors independently and simultaneously contribute to functional disability in individuals with PTSS.

2. Predictor Variables and mTBI Outcomes

This study has focused primarily on the role of PTSS on outcomes following mTBI. The preceding section has discussed the results and implications of these findings in detail. However, this study also found that other variables included in the regression analyses also contributed to mTBI outcomes. Given the significance and implications of these additional findings, these results will also be discussed in the following section.

a. Stress and Post-Concussion Symptoms

Excess stress has been widely noted in literature to impact the wellbeing of individuals (Schneiderman et al., 2005). Therefore, it is reasonable to consider that stress impacts mTBI recovery. Various research studies have discovered that stress is a strong predictor of developing PCS (Wijenberg et al., 2017; Silverberg et al., 2015; Ponsford et al.,

2011; Carroll et al., 2004). Consistent with this extensive body of evidence, this study also found that stress made a significant and unique contribution to PCS severity after mTBI. A possible explanation for this may be that stress impacts neurophysiological networks, altering the brains physiology, intensifying symptoms and making people less resilient and adaptable to personal and environmental stressors (Silverberg et al., 2017). High levels of stress experienced post-mTBI has been observed to precipitate the development of depression and PCS (Silverberg et al., 2017). It is unclear whether this neurobiological alteration is caused by mTBI pathophysiology, the experience of a stressful event or both (Silverberg et al., 2017; Griesbach et al., 2011). Nevertheless, stress it seems is a likely risk factor for negative mTBI outcomes.

b. Medical History and Post-Concussion Symptoms

Medical history made a unique and significant contribution to mTBI outcomes in this study. Medical history includes all past illnesses and treatments of an individual except TBIs. Past research has complimented these findings (Carroll et al., 2004; Rickards et al., 2020; Theadom et al, 2016). Theadom et al. (2016) discovered that medical history was an important predictor of outcomes after mTBI (Theadom et al., 2016). In their longitudinal study medical history such as high alcohol use and use of psychotropic medication were associated with poorer outcomes at 12-months post-mTBI injury (Theadom et al., 2016). Additionally, chronic pain, according to Meares et al. (2008) and Rickards et al. (2020) was associated with acute PCS post-mTBI. However, another study showed that individuals with non-head injured chronic pain reported frequent and severe PCS with heightened levels of self-perceived cognitive deficits (Iverson & McCracken, 1997). This suggests that pain in general whether in relation to an mTBI or not can cause PCS. Future research should consider investigating the contribution of medical history on mTBI outcomes further. Although this may be faced with some difficulty. Research on this topic is vast due to “medical history”

being broad and heterogenous, normally including characteristics such as physical, biological and psychological illnesses. Therefore, medical history in future needs to be defined. For example, according to Rickards et al. (2020) pre-injury neurological illnesses, have been identified to increase the risk of PCS. However, this observation is met with little research indicating which specific neurologic disorders grant this premise (Carroll et al., 2004; Kay et al., 1992; Thornhill et al., 2000). Identifying specific medical illnesses which contribute to negative mTBI outcomes, would allow clinicians to apply predictive prognostic methods to treatment interventions.

c. Gender and Functional Status

The female gender has been vastly noted to increase the risk of PCS (Rickards et al., 2020; Bazarian et al., 1999; Carroll et al., 2004; Scopaz & Hatzenbuehler, 2013; Varriano et al., 2018; Ponsford et al., 2012; Albanese et al., 2017; Varriano et al., 2018; Dikmen et al., 2017; Theadom et al., 2016; Carrol et al., 2014). Gozt et al. (2021) and Ewing-Cobbs et al. (2018) both stipulated the importance gender plays in the development of PCS and functional status. A recent study by Hannah et al. (2021) found that females were 62% more likely of experiencing a sport related mTBI then males. In the general population however, according to Faul et al. (2010) females sustain fewer mTBI than males. Interestingly, females experience greater post-injury severity which impacts functional status (Arnold, 2014; Varriano et al., 2018). Symptoms often reported by females which affect functional status include problems with concentration, processing speed, light-headedness, fatigue and distorted vision (flyspots) (Arnold, 2014). Overall, females experience significantly more symptoms than males, specifically post-concussion migraines and neuropsychiatric problems such as anxiety and depression (Hannah et al., 2021; Sufrinko et al., 2017; Brooks et al., 2018; Baker et al., 2016; Bazarian et al., 2010; Brickell et al., 2017).

There are several theories which attempt to understand why females are at a greater risk. Firstly, hormones. Although there is limited research, it has been suggested that sustaining a mTBI during a certain phase of the menstrual cycle may negatively affect recovery time (Wunderle et al., 2014; Gallagher et al., 2018). Secondly, pre-injury psychiatric issues. Pre-injury mental health has been vastly noted in literature to implicate mTBI outcomes. Many studies have demonstrated that pre-injury mental health is a predominant risk factor for PCS and implicated functional status (Rickards et al., 2020; Faulkner et al., 2021a; Faulkner et al., 2020, Silverberg & Iverson, 2011; Silverberg et al., 2015). Interestingly, a recent study has purported that females are at a higher risk of psychiatric illnesses then males (Gulland, 2016). Arguably, this connection may provide some insight into why females, rather than males are more prone to developing adverse effects to mTBI. Thirdly, social support. although there is no clear evidence, lack of social support has been noted to be a risk factor for developing PCS (Rickards et al., 2020). However, research proclaims that males often experience less social support then females (McKenzie et al., 2018) it should not be ruled out entirely. For example, it is well documented that lack of social support increases the risk of developing post-partum depression in females (Corrigan et al., 2015). Therefore, logically, lack of social support should be investigated more within the mTBI population and specifically in terms of gender roles as often, females are solely responsible for taking care of families. There is limited research regarding the sex differences in mTBI severity, recovery and outcomes. What is available has not been thoroughly evaluated. Consequently, further research will benefit from identifying the reasons for why females are at a greater risk of mTBI and adverse effects.

d. Depression and Functional Status

Depression is a chronically debilitating mental state, which is common in all populations and is considered a serious medical illness, affecting how an individual feels,

thinks and behaves (Sadock et al., 2015). Depression affects motivation levels, appetite, sleep, mood (irritability), reduces personal interests, increases anxiety and engulfs an individual with sadness which often impairs one's ability to perform daily tasks (Sadock et al., 2015). Additionally, physical symptoms of depression can consist of fatigue (Targum & Fava, 2011), decreased pain tolerance (Zambito Marsala et al., 2015), back pain, aching muscles (Robertson et al., 2017) and headaches (Breslau et al., 2000). Depression is heterogenous, with a unique presentation within everyone. The consequences of depression are significant, causing severe functional impairment and often leading to other comorbid disorders such as anxiety (Sadock et al., 2015).

In line with previous research, depression has been noted to affect functional status in individuals with mTBI, thereby affecting recovery (Kellezi et al., 2017; Zahniser et al., 2019; Rickards et al., 2020; Silverberg & Iverson, 2011; Lepage et al., 2016). For example, Zahniser et al. (2019) found that symptoms of both depression and anxiety significantly predicted subsequent functional limitations. In addition, experiencing depression shortly after post-injury, predicted poorer functional outcomes affecting return to work, housework and social life (Kellezi et al., 2017). This finding suggests that depression significantly affects functional status within the mTBI population and delays recovery time.

Understanding the underlying causes of depression post-mTBI is currently under examination (Lepage et al., 2016). Several theories have been identified as possible explanations. Firstly, neurometabolic changes in the brain caused by the mTBI can potentially precipitate a depressive disorder (Silverberg et al., 2017). A study by Roy et al. (2019) found that LOC and altered mental states (AMS) caused by the mTBI can contribute to PCS and depressive symptoms. At one-month post-mTBI the study found that among the participants who experienced both LOC and AMS reported higher rates of depressive (44%) and PCS (54%) compared to other groups. Furthermore, AMS was associated with depressive

symptoms at one and six months and PCS at one-month. LOC was associated only with PCS at one-month. These findings suggest that AMS predicts post-mTBI depressive symptoms, whereas LOC is a predictor for PCS post-mTBI.

Secondly, that the injury itself causes alterations, physiologically decreasing an individual's ability to be resilient and adaptable, thus precipitating depression (Silverberg et al., 2017). Thirdly, pre-injury depression can be exacerbated because of the significant symptom overlap precipitating the PCS (Silverberg et al., 2017; Rickards e t al., 2020). It is unclear whether, depression was caused by the physiological alterations of the brain due to the mTBI or because of an inability to adapt to changes. Therefore, clinicians should address, not only depression but resilience (a feature of psychological flexibility) to prevent ongoing negative outcomes.

Overall, depression has been rigorously examined and has been found to affect the functional status in individuals with mTBI. Furthermore, depression has also been noted to affect mTBI recovery. In fact, experiencing depression shortly after sustaining an mTBI can predict poorer functional outcomes, preventing individuals from returning to pre-injury functioning. There are several theories, that attempt to explain the association of mTBI and depression. However, there is an uncertainty regarding the biological influence the impact of the injury has on the outcomes, likewise how post-injury depression and mTBI become associated. Therefore, it is important to note and consider the significant impact depression has on mTBI recovery.

3. PTSS, Psychological Flexibility and Fear Avoidance

a. PTSS and Psychological Mechanisms

The further aim of the study was to identify the role of psychological flexibility and fear avoidance on PTSS in individuals with mTBI. It was hypothesised that psychological

inflexibility and fear avoidance would be associated with PTSS. The results support this prediction. First, psychological inflexibility and fear avoidance was positively correlated with PTSS. That is, the higher the inflexibility and fear avoidance, the higher the levels of PTSS in individuals with mTBI. Second, a multiple linear regression model was used to factor in the influence of other variables known to PTSS. These analyses found that psychological flexibility and fear avoidance continued to make a significant and unique contribution to PTSS in mTBI. In addition, these analyses also found that education status and depression also positively contributed to PTSS. The following section will discuss each of these results in more detail.

b. PTSS and Psychological Flexibility

There is a wealth of research that illustrates that psychological flexibility is a psychological mechanism that contributes to the development of psychological distress (for review see Kashdan & Rottenberg, 2010). This study contributes to this literature by providing proof that psychological inflexibility positively contributed to PTSS in mTBI. Previous research supports this finding (Dutra & Sadeh, 2018; Meyer et al., 2019; Schramm et al., 2020; Jones, 2016). Recent research has extended these findings to mTBI. For example, Faulkner et al. (2021a) conducted a study with the objective to examine psychological flexibility as a mechanism which contributes to psychological distress, functional status and PCS. The study contained 169 treatment seeking adults with mTBI. Participants were asked to complete an array of self-report measures of PCS, psychological distress such as anxiety, stress and depression and measures which assessed functional status within four weeks of entry to an mTBI clinic. Furthermore, general measures such as the (Acceptance and Action Questionnaire), as well as a context-specific (Acceptance and Action Questionnaire—Acquired Brain Injury) measure of psychological flexibility were administered. The study used a simple linear regression model and found

that psychological flexibility made a significant contribution to the prediction of PCS and functional status (Faulkner et al., 2021a). Although more research is needed, these results suggest that psychological flexibility may play a critical role in the development of psychological distress following mTBI. This study extends on this body of work and illustrates that psychological inflexibility may also contribute to the development of PTSS following mTBI.

It is evident that psychological inflexibility contributes to mental distress such as PTSS (Bond et al., 2011; Madusa & Tully, 2012). Therefore, it is important to understand how psychological inflexibility contributes to the development of PTSS. Firstly, if an individual is psychologically inflexible, they are more likely to experience unhelpful thought patterns associated with the trauma such as unhelpful thinking styles (catastrophising, all-or-nothing thinking, over-generalising, personalisation). Secondly, individuals will also be more likely to experience intrusive thoughts and will engage in rigid behavioural patterns such as avoidance, to restrict experiencing those feelings, memories, and thoughts, which will thus maintain PTSS.

According to Jones (2016) the psychological flexibility model suggests that avoidance or negation of internal experiences (intrusive thoughts) relates to an increased frequency of the avoided internal experience through experiential avoidance. This further causes an individual to experience cognitive fusion and a lack of contact with the present moment (Jones, 2016). Cognitive fusion can be defined as a mental process through which an individual becomes entangled in thoughts, perceptions and memories, congruent with an event (Jones, 2016). For example, an individual who experienced a trauma, and has unhelpful thinking styles (all-or-nothing thinking or catastrophising) may also experience feelings of guilt, helplessness, blame and fear. This cognitive fusion can in turn cause a lack of contact with the present moment and increase the use of avoidance as a form of

escaping these thoughts “I am unsafe” and feelings “I feel scared” (Jones 2016). Attempts to avoid uncomfortable thoughts, memories, feelings, physical sensations and other internal experiences can be maintained through negative reinforcements (a feeling of short-term relief achieved from avoidance) thereby increasing the likelihood that the behaviour will continue. Psychological inflexibility thus elicits this cycle and therefore contributes to the maintenance and development of PTSS.

c. PTSS and Fear Avoidance

In addition to psychological flexibility, this study also investigated the underlying role of fear avoidance on the development of PTSS following mTBI. It was found that fear avoidance significantly and positively contributed to PTSS. This is not surprising as avoidance is a central feature of PTSD and is often proposed as a mechanism of PTSD development (Sripada et al., 2013; Ehlers & Clark, 2000). Sripada et al. (2013) found that individuals who avoided trauma reminders and cues, were at an increased risk of experiencing and maintaining PTSS than those who did not. In addition, those who engaged in avoidance behaviour experienced increased PTSS over time (Sripada et al., 2013). This finding supports the fear avoidance model which is widely used for both chronic pain and PTSD (Vlaeyen, & Linton, 2000). The fear avoidance model for chronic pain describes the maladaptive cognitive processes such as catastrophising, which help to maintain the fear of pain and the avoidance of activities that cause more pain (Vlaeyen, & Linton, 2000). Similarly, for PTSD, avoidance is used for the fear of relieving the trauma (emotional pain). For example, PTSS were found to increase the levels of anxiety sensitivity, predisposing individuals to catastrophising, in turn leading to higher levels of fear avoidance (López-Martínez et al., 2014). Within a mTBI context, an anxiety response might be prompted in anticipation of activities either involving high physical and/or mental exertion, or situations which involve sensory stimulation catastrophised by the

individuals as dangerous, intolerable, or likely to worsen PCS (Cassetta et al., 2021). Consequently, individuals learn to avoid these perceived threatening situations, causing these avoidance behaviours to be reinforced by the non-occurrence of a feared consequence (Vlaeyen & Linton, 2000). Recent studies have demonstrated that fear avoidance behaviour is associated with concurrent (Silverberg et al., 2017; Wijenberg et al., 2017) and later (Silverberg et al., 2018) PCS burden. These findings are congruent with this studies results. What is apparent is that there is a significant gap in literature targeting fear avoidance and PTSS. This study provides initial evidence to bridge this gap, however, future studies would benefit from investigate this role further within an mTBI context.

4. PTSS and Other Predictor Variables

Linear regression analysis also found that, in addition to fear avoidance and psychological flexibility, educational status and depression also made a significant and unique contribution to PTSS following mTBI. The following section will briefly discuss these results.

a. Education Status Contributes to PTSS

Education is a culturally formed construct and is defined as the process of receiving or giving systematic instruction, especially at a school or university context (Woodford et al., 2020). Education is pivotal in determining and predicting life outcomes such as employment, income, social status and influences attitudes and wellbeing. In the Western domain, education is often used by people to shape their ‘social identity’ and their perceptiveness and ability to adapt to changes (Woodford et al., 2020). Therefore, it is not surprising that there is a strong link between education status and psychological flexibility. For example, low levels of education increase risk of psychological inflexibility, whereas

higher levels of education show higher levels of psychological flexibility (Dalgard et al., 2007). In fact, literature reveals that low levels of education increase psychological distress in both genders and is a risk factor for psychopathologies (Dalgard et al., 2007). Consequently, low levels of education and thereby psychological inflexibility could contribute or increase the risk of PTSS post-mTBI.

A recent study by Stein et al. (2019) found that risk factors for probable PTSD at six-months post-mTBI included low levels of education. Various studies have supported this finding stating that education status is a significant predictive factor in not only contributing to PTSS but also to PCS and functional status (Cnossen et al., 2017; Rickards et al., 2020; Stein et al., 2019). Rickards et al. (2020), and van deer Naalt (2017), both stipulated that one of the main variables in predicting PCS and affecting functional status is education. This was further supported by Dalgard and colleagues (2007) who found that low level of education significantly impacts functional status as it decreases a sense of mastery, decreases social support, increases many negative life events (with men), results in low household income and unemployment. These findings suggest that education is an imperative variable to mTBI outcomes. Furthermore, this study also found that education status is a risk factor for the development of PTSS.

b. Depression Contributes to PTSS

Depression is a tremendously common co-occurring diagnosis in individuals with PTSD (Gros et al., 2012). Research has found that among people who have or have had a diagnosis of PTSD, an estimated 48% to 55% also have experienced current or previous depression. Although, the symptomology of depression and PTSD is different, some similarities do exist, difficulty with sleep, emotional outbursts (anger or aggression) and loss of interest in activities (Flory & Yehuda, 2015). Another major similarity between

PTSD and depression is that both are associated with symptoms of cognitive impairment (Gros et al., 2012). There is extensive research which demonstrates that PTSD has a direct influence on the development of depression (Flory & Yehuda, 2015; Gros et al., 2012; Rytwinski et al., 2013). For example, experiencing PTSS can be distressing and debilitating, therefore, PTSS itself can cause depression to develop (Flory & Yehuda, 2015).

Depression was found to be a significant variable which contributed to PTSS in this study. However, research regarding the direct role of depression on PTSD is minimal, as such not much is known between this association. What has been found is that people with depression are at a higher risk of experiencing trauma, than those without depression (Sadock et al., 2015) therefore increasing the likelihood of PTSD (Gros et al., 2012). It is also known that PTSD can be a potential outcome after sustaining an mTBI (Sareen, 2014). As such it is not uncommon for individuals with mTBI to experience both PTSS and depression, both of which significantly affect functioning (Sareen, 2014). It is possible that depression can impact PTSS by exacerbating some of the shared symptomologies affecting an individual's emotions, mood, behaviour, motivation, interests, and energy levels. In fact, depression itself is a common symptom of PTSD. Consequently, it is conceivable that depression has a significant role in the contribution of PTSS among those with mTBI, and as such should be further explored.

5. Mediation Analysis

The third and final aim of this study was to explore the role of psychological flexibility and fear avoidance as underlying psychological mechanisms on the relationship between PTSS and outcomes (PCS and functional status). To achieve this, meditation analysis was conducted. It was hypothesised that psychological flexibility and fear

avoidance would independently have a mediating effect on the relationship between PTSS and mTBI outcomes. This hypothesis was partially supported by the study. Although psychological flexibility and fear avoidance, when independently entered into the mediation model, meditated the relationship between PTSS and mTBI outcomes; these meditations were partial. This suggests that the effects of PTSS on mTBI outcomes cannot be fully explained by these psychological mechanisms. Interestingly, when multiple meditation models were computed (where both psychological flexibility and fear avoidance were entered into a mediation model), the partial indirect effects of these mechanisms on the relationship between PTSS and mTBI were both significant for functional disability. When PCS was the outcome variable, only psychological flexibility had a significant indirect effect. These findings will now be discussed.

a. The Mediation Effects of Psychological Flexibility on the Relationship between PTSS and Post-Concussion Outcomes

The study found that psychological flexibility mediated the relationship between PTSS and PCS. However, this relationship was partial suggesting that the relationship between PTSS and PCS can be explained in part by psychological flexibility. Psychological flexibility is conceptualised as a psychological mechanism as it wields an influence on the relationship between psychological factors (i.e., rumination, impulsivity) and health outcomes (i.e., psychological distress, pain, fatigue; Morris & Mansell, 2018). Meaning, high levels of psychological inflexibility can cause inflexible implementation of these negative factors, which maintain psychological symptoms. Recently, Faulkner et al., (2021a) found that psychological flexibility partially mediated the relationships between depression, anxiety, stress, and PCS. Based on these findings, the authors concluded that targeting psychological flexibility may influence the effects that these affect states have on PCS. This study extends on these findings and provides novel evidence that psychological flexibility

also partially mediates the effects of PTSS on PCS. Although further research is needed to replicate these findings, these results suggest that if an individual with mTBI presents with PTSS, increasing psychological flexibility may mitigate the impact these psychological symptoms have on PCS.

b. The Mediation Effects of Psychological Flexibility on the Relationship between PTSS and Functional Status

PCS have been widely noted to impact an individual's functional status. As such the present study examined the effects of psychological flexibility on the relationship between PTSS and functional status. The study found that psychological flexibility partially mediated the relationship between PTSS and functional status. There was an indirect effect of PTSS on functional status through psychological flexibility and there was a direct effect of PTSS on functional status, indicating that the mediation was partial. The present findings are in support of previous research. It has been repeatedly stated that PTSS has a significant effect on the functional ability of individuals (Leserman et al., 2005; Kellezi et al., 2017; Magruder et al., 2004). Aase et al. (2018) discovered that individuals with mTBI and PTSS experienced poorly on measures of recall, greater pain catastrophising, greater pain intensity, and greater illness-focused coping than in comparison to individuals with mTBI alone. Furthermore, previous research using a series of multiple mediation analyses showed that psychological flexibility had a significant indirect effect (partial mediation) on the relationships between psychological distress, PCS and functional status (Faulkner et al., 2021a). As such is it evident that PTSS increases functional disability after mTBI, and this relationship is explained in part by psychological flexibility.

c. The Mediation Effects of Fear Avoidance on the Relationship between PTSS and Post-Concussion Outcomes

The study found that fear avoidance mediated the relationship between PTSS and PCS. However, this relationship was partial suggesting that the relationship between PTSS and PCS can be explained in part by fear avoidance. Fear avoidance is conceptualised as a psychological mechanism as it utilises an influence on the relationship between psychological factors (i.e., catastrophising, avoidance) and health outcomes (i.e., psychological distress such as anxiety and PCS; Greenberg et al., 2020). Simply explained, high levels of fear avoidance can result in the rigid implementation of these factors (pain catastrophising, avoidance) which maintain psychological symptoms (anxiety, PCS). Recently, Greenberg et al. (2020) found that pain catastrophising and avoidance, key elements of the FAM, partially mediated the relationship between psychological distress (anxiety) and PCS. Furthermore, the study found that pain catastrophising was less reliable, albeit a numerically stronger mediator and explained more variance in PCS than in avoidance (Greenberg et al., 2020). Although both mediators, pain catastrophising and avoidance did not significantly differ in strength. Based on these findings the authors could conclude that targeting fear avoidance may impact the effects that these affect states have on psychological distress and PCS. The current study further extends on these findings and provides novel evidence that fear avoidance partially mediates the effects of PTSS on PCS. Further research is needed to replicate these findings. Although the results suggest that if an individual with mTBI presents with PTSS, treating fear avoidance may mitigate the impact these psychological symptoms have on PCS.

d. The Mediation Effects of Fear Avoidance on the Relationship between PTSS and Functional Status

Along with fear avoidance contributing to PCS, the study found that it also impacts functional status after mTBI. This finding builds on existing evidence, upon which fear avoidance has been found to be significant in debilitating functional status (Maeng & Milad,

2017). The study found that fear avoidance was observed to mediate the relationship between PTSS and functional status. Albeit, this mediation was partial, suggesting that this relationship can only be explained in part by fear avoidance. Fear avoidance as a mechanism wields an influence over psychological factors such as pain catastrophising or thought catastrophising, including limiting behaviour such as avoidance of physical (kinesiphobia) or cognitive (cogniphobia) activities (Cassetta et al., 2021). Furthermore, catastrophising and avoidance are central psychological factors in PTSS. The majority of individuals with PTSS experience cognitive distortions such as catastrophic thinking (expecting the worst to happen without considering other possibilities) and avoidance (Sadock et al., 2015; Sareen, 2014). Combined, both significantly impact functional status in individuals post-mTBI. Chaput et al. (2016) found that higher levels of pain catastrophising were related to adverse early mTBI outcomes. Given this finding early detection of catastrophising may prevent or minimise the development of functional disabilities and PCS. Furthermore, catastrophising has been noted to knowingly exacerbate existing symptomologies. Gilliam et al. (2019) performed a series of multiple parallel mediation analyses. The findings revealed that pain catastrophising fully mediated the relationship between PTSS and pain outcomes such as pain severity and pain interference. Based on these findings, pain catastrophising may represent an important cognitive mechanism through which PTSS influence the experience of chronic pain. In relation to mTBI, this suggests that catastrophising may influence common symptoms such as head pain, thereby affecting functional status.

Likewise, avoidance, has been found to affect functional status. According to Vlaeyen & Linton (2000) fear avoidance is a key element to symptom persistence. For example, negative appraisals of symptoms and their consequences (catastrophising) were found to lead to avoidance of physical activities (kinesiophobia) believed to trigger symptoms (Vlaeyen & Linton, 2000; Cassetta et al., 2020). In relation to individuals with mTBI these activities can

include high physical and/or mental exertion or situations (e.g., with a lot of sensory stimulation) that are viewed as dangerous, intolerable, or likely to worsen PCS at least transiently (Cassetta et al., 2020). As a result, the individual will learn to escape from or avoid these perceived threatening situations (Cassetta et al., 2020). A recent study by Cassetta et al. (2021) noted that avoidance affects perceived disability. The study discovered that higher levels of avoidance, resulted in more severe perceived disability. These findings are in line with the current studies results. Therefore, detecting psychological factors associated to fear avoidance (such as catastrophising and avoidance) at the early stages post-mTBI, may help mitigate the risk of poor outcomes. Future research should investigate the mediation effects of fear avoidance on the relationship between PTSS and functional status to replicate these findings.

6. Multiple Meditation

Both psychological flexibility and fear avoidance were seen to significantly impact the relationship between PTSS and outcomes (PCS and functional status) when entered into independent meditation models. However, the study wanted to further determine if psychological flexibility and fear avoidance explain the association between PTSS and outcomes when modelled simultaneously using multiple mediation analysis. This has the potential to provide valuable insights for clinicians as it can provide information on which psychological mechanism may be more important to target in treatment to mitigate the effects that PTSS has on mTBI outcomes.

a. The Role of Psychological Flexibility and Fear Avoidance between PTSS and Post-Concussion Symptoms

The objective of the research question was to attain evidence of a relationship between psychological flexibility and fear avoidance between PTSS and PCS. The results

demonstrated that, when modelled simultaneously, psychological flexibility partially mediated the relationship between PTSS and PCS, whereas fear avoidance did not. This result implies that psychological flexibility and fear avoidance are separate mechanisms. In isolation both are effective on outcomes however, when used in double mediation it is seen that psychological flexibility continues to partially mediate the relationship between PTSS and PCS. These results suggest that clinicians may need to target psychological flexibility over fear avoidance, as when these mechanisms are both considered, psychological flexibility has the most significant effect on the relationship between PTSS and PCS. There is no other research to compare these findings too, as such these results provide new insight into the understanding of the mechanisms that underly the relationship between PTSS and PCS. Future research should explore these mechanisms within a larger longitudinal study which investigates the relationship between PTSS and PCS in relation to these psychological mechanisms.

b. The Role of Psychological Flexibility and Fear Avoidance between PTSS and Functional Status

The study further examined the role of psychological flexibility and fear avoidance between PTSS and functional status using multiple mediation analysis. The results indicated, when modelled concurrently, that psychological flexibility and fear avoidance partially mediated the relationship between PTSS and functional status. This result implies that both mechanisms contribute to diminished functioning. These results indicate that although psychological flexibility and fear avoidance are separate mechanisms, they both significantly contribute to functional disability, which is in line with the hypothesis. Based on these findings, clinicians may need to consider treating both psychological flexibility and fear avoidance to maximise the negative effects that PTSS have on mTBI outcomes. There is no research known to the author that has investigated the mediation of these

mechanism on the relationship between PTSS and functional status. The insight gained from these results presents new evidence which future studies should explore on a larger scale in order to replicate these findings, therefore providing more generalisability.

7. Summary of Findings

Psychological flexibility and fear avoidance have been identified to contribute to negative recovery outcomes in mTBI populations (Faulkner et al., 2020; Faulkner et al., 2021a; Wijenberg et al., 2017; Cairncross et al., 2021; Cassetta et al., 2021; Snell et al., 2020). These mechanisms have been found to increase the risk of developing adverse mental health outcomes such as PTSD in other populations (Sripada et al., 2013; Schramm et al., 2020; Meyer et al., 2019). The current study revealed that psychological flexibility and fear avoidance may contribute to PTSS in mTBI. This finding is in line with previous research which found that this mechanism mitigates effects of PTSS in other populations (Dutra & Sadeh, 2018) or likewise that psychological inflexibility contributes to PTSD (Meyer et al., 2019). PTSD is a significant risk factor within the mTBI population (Sareen, 2014) therefore, it is important to assess the contribution of psychological flexibility within this relationship. Furthermore, fear avoidance among individuals with mTBI has been seen to contribute to PTSD, as both fear and avoidance are integral to the symptomology which evoke the fear circuit activation which causes more severe PTSS (Sripada et al., 2013). Overall, the current study has unearthed new information thus adding to the existing body of research in this field.

8. Implication of Findings

These findings provide crucial insight into how clinicians should proceed with treating individuals with mTBI. Treatment interventions should target psychological flexibility and fear avoidance, as both have been examined to contribute to the

development of PTSS. Furthermore, the findings of the current study also found that PTSS contribute to PCS and functional disability. Based on these findings, clinicians need to provide appropriate and evidence-based intervention treatments which target PTSS and these psychological mechanisms, thereby, mitigating negative outcomes post-mTBI. According to research acceptance and commitment therapy (ACT) and cognitive behavioral therapy (CBT) have been successfully used to treat psychological flexibility and fear avoidance and will be discussed in more detail.

9. Acceptance and Commitment Therapy

A large body of literature has discussed the positive effects of ACT on treating psychological inflexibility (Freeman, 2010; Whiting et al., 2019; Dindo et al., 2020; Wang et al., 2020; Fang et al., 2020; Bohlmeijer et al., 2011; Dahl et al., 2004). For example, Scott et al. (2016b) aimed to assess the changes to psychological flexibility following ACT among participants who experienced chronic pain. The results of the study revealed that in addition to increased psychological flexibility, there were significant improvements in pain, functioning, depression, pain acceptance and cognitive fusion (Scott et al., 2016b). Considering many of these psychological factors such as depression, pain, and diminished functional ability are comorbid for people post-mTBI, it can be suggested that based on these results, ACT is an appropriate treatment intervention for the mTBI population.

ACT is a type of psychotherapy which was developed by Steven Hayes in 1982 in order to create a mixed approach which integrated both covert conditioning and behaviour therapy (Freeman, 2010). ACT uses constructs such as mindfulness and acceptance which help individuals accept difficulties that come with life, focusing directly on psychological flexibility (Silberstein et al., 2012; Prochaska & Norcross, 2018). Studies have shown that engagement in mindfulness decreases activity in the right medial prefrontal cortex (Langer

& Padrone, 1992). Mindfulness also alters activation in the dorsal medial prefrontal cortex, rostral anterior cingulate cortex and insular (Chiesa & Serretti, 2010; Hölzel et al., 2007; Young et al., 2018). These results suggest that mindfulness is an effective method in implementing changes.

However, the core origin of ACT is that psychological suffering is generally caused by experiential avoidance. Consequently, ACT directly targets all facets of psychological flexibility such as, acceptance (willingness to experience difficult emotions), experiential avoidance (opposite of acceptance), cognitive defusion (loosening of the dominance of thoughts over experience and actions), flexible present-focused awareness (purposeful, non-judgemental attention to current experiences), self-as context (viewpoint in which there is a distinction between the person having an experience and the experiences themselves), values-based action (modelling personal values), and committed action (flexible persistence in values-based and goal directed behaviour (Hayes et al., 2011; Scott et al., 2016c). Treating these facets mitigates negative outcomes, while simultaneously increasing psychological flexibility by guiding individuals to adapt to changes (Hayes et al., 2012; Prochaska & Norcross, 2018). For example, when ACT is used with chronic pain, the goal is to help individuals disengage from ineffective efforts to control or avoid pain (Scott et al., 2016b). Instead, ACT focuses on engaging in efforts to reach positive goals while following personal values (Scott et al., 2016b). Considering it is normal for individuals to avoid unpleasant experiences makes ACT rather counterintuitive. Nevertheless, ACT encourages individuals in the presence of potentially intrusive psychological experiences such as thoughts and feelings, not to view them as barriers rather as opportunities for acceptance and change (Scott., 2016b). Briefly, ACT allows individuals to learn to be comfortable in uncomfortable situations.

Dindo and colleagues (2020) developed a one-day ACT informed workshop for veterans who had an existing mTBI. Dindo et al. (2020) performed a pilot randomised control trial, comparing the results of interventions such as ACT to treatment as usual (TAU). At three-months post workshop, participants in the ACT group showed improvements in psychological flexibility and had reduced stress, anxiety, and depression scores. These findings suggest that ACT may be beneficial in addressing not only psychological flexibility but also psychosocial stressors which significantly impact recovery following mTBI.

Another study by Sander and colleagues (2020) examined 93 individuals with medically documented mild to severe TBI. The participants were assigned to two groups, a control, and an ACT group. Participants received eight weeks of ACT. The results indicated that the participants in the ACT group showed significant improvements with psychological distress and had increased levels of psychological flexibility and commitment to action (Sander et al., 2020). Based on these findings it appears that ACT is effective in the treatment of psychological inflexibility among individuals from diverse medical backgrounds including TBI, while significantly improving psychological flexibility and distress.

10. Cognitive Behavioural Therapy

Cognitive behaviour therapy (CBT) has been extensively used to treat fears, anxieties, and avoidance (Sadock et al., 2015; Prochaska & Norcross, 2018; Roberts et al., 2009; Bisson et al., 2007; Seidler et al., 2006; Kar, 2011; Mendes et al., 2008). According to the American Psychological Association (2021) CBT is a form of psychological treatment that has demonstrated effectiveness for a range of psychological problems such as depression, anxiety disorders, alcohol and drug use, marital problems, eating disorders,

and severe mental illnesses (Prochaska & Norcross, 2018). Many research studies suggest that CBT leads to significant improvement in functioning and quality of life (APA, 2021). Furthermore, CBT has been demonstrated to be as effective, or more effective than, other forms of psychological therapy or psychiatric medications in treating fear-based disorders (Sadock et al., 2015; Prochaska & Norcross, 2018). CBT focuses on treating core beliefs (faulty or unhelpful ways of thinking), unhelpful behaviours and maladaptive coping styles such as fear avoidance (Prochaska & Norcross, 2018).

Research has demonstrated the efficacy of CBT on treating fear avoidance. For example, recently, Baez et al. (2018) evaluated the effectiveness of CBT and psychoeducation in treating fear-avoidance beliefs in patients with acute, subacute, and chronic low back pain (LBP). The meta-analysis found that patient centred, and personalised CBTs were most effective when compared with a control treatment. Both CBTs and psychoeducation strategies proved to be clinically meaningful in diminishing fear avoidant beliefs, although, CBT was observed to be more statistically significant (Baez et al., 2018). This finding indicates that CBT is effective in treating fear of pain and avoidance, two commonly seen constructs with individuals post-mTBI.

The mechanisms of action in CBT on PTSD are diverse. There are various cognitive distortions seen in PTSD (Kar, 2011). These distortions include, perceiving the world as dangerous, feeling guilty about outcomes that could not have been prevented, or seeing oneself as powerless or inadequate (Kar, 2011). For example, a study indicated that PTSD is linked with negative beliefs about one's personal identity, thereby influencing self-esteem and interpersonal relationships (Christensen et al., 2004). These symptoms are often seen in depression therefore it is not surprising that PTSD often co-occurs with depression (Kar, 2011). CBT focuses on how an individual's affect and behaviour determines the way he/she thinks and behaves including how they see the world around

them, thus, mitigating maladaptive thinking styles such as fear avoidance (Kar, 2011). Given this, there is a strong argument for the effectiveness of CBT on PTSD.

Lastly, there is limited data on the efficacy of CBT on mTBI. However, Hsieh et al. (2012) examined two participants (case study approach), one with severe the other with moderate TBI. Both participants also experienced anxiety and depression. The study revealed that both participants experienced improvement in moods, anxiety and avoidance (coping style). These results suggest that CBT may be effective for individuals with TBI's. Another study by Gómez-de-Regil et al. (2019) compared psychological interventions on a sample of participants who had experienced TBI's. The studies results revealed that CBT out shown other therapeutic methods as the preferred therapeutic approach for treating behavioural and emotional disturbances (Gómez-de-Regil et al., 2019). It was further stipulated that CBT reduced anger, depression, anxiety and PTSS while improving coping methods (Gómez-de-Regil et al., 2019). These findings suggest that it may be advantageous in treating fear avoidance, psychological distress (anxiety, depression, PTSD) and mTBI with CBT.

11. Limitations

There are several limitations that need to be addressed when interpreting the results of this study. Although this study appears to be the largest based on the number of participants (known to the author), future research should include a larger participant pool, thus increasing the generalisability of the findings.

The current study observed that being female was significantly related to increased levels of PTSS, PCS and functional disability. There were 65.7% of female participants in this study, and only 34.3% of males. Consequently, the impact of gender on mTBI outcomes should be treated with caution given the over representation of females in this

study. This discrepancy may be due to females being more willing to seek treatment rather than males (Thompson et al., 2016). Therefore, future research should encourage greater participation of males by normalising help-seeking behaviour when faced with mTBI and including a more equal ratio of female/male participants to assess whether gender is a significant risk factor.

The study was a cross-sectional design and as such causality cannot be inferred, limiting the inferences that can be made from the data. For example, the associations between examined variables in the mediation models appear bidirectional, with PTSS increasing PCS and reduced functional status through the mediating roles of psychological flexibility and fear avoidance. Likewise, it is impossible to infer whether it is solely the psychological mechanisms that increase PTSS which thus increases PCS and impairs functional status. Future research should consider exploring these relationships within a longitudinal design to examine how these relationships might evolve or change over time. This is especially important considering PCS and PTSD symptoms transpire with time.

A significant limitation is that participants were recruited approximately eight weeks from time of injury, and then assessed within one month of entry to an outpatient mTBI treatment service. The time frame of experienced symptoms does not meet the diagnostic criteria for either PTSD or PPCS. For an individual to be diagnosed with PTSD, symptoms must be present for six months (Sadock et al., 2015) and to be diagnosed with PPCS, symptoms must be present for three months (Sadock et al., 2015). Future research should aim to explore psychological flexibility and fear avoidance over multiple time points to investigate its role in the development and maintenance of PTSS and PCS.

In addition, it is important to note that participants were recruited from concussion services. These individuals were already experiencing difficulties managing their PCS,

consequently, this sample is not representative of the wider mTBI population. As such the study's findings cannot be generalised to the wider mTBI population. Future research should target recruiting participants from the general population who had experienced an mTBI within a certain time frame.

The psychometric measures in this study were administered in the same order to all recruited participants. So, order effects and fatigue effects cannot be ruled out as contributing to the results (Süss et al., 2000; Kaplan & Saccuzzo, 2013). Fatigue could have caused participants to respond more carelessly to items. It may be more effective in future for clinician to assist individuals who appear to struggle more with concentration and fatigue by reading out loud the questionnaires to allow for more accurate results.

The use of retrospective self-report measures may be faced with a larger likelihood of measurement error in comparison to Clinician Administered Interviews (Kaplan & Saccuzzo, 2013). It is common for individuals who experience avoidance (in the general population) to underreport symptoms (Sadock et al., 2015). Consequently, it may have been possible that individuals with existing avoidance underreported symptom presentations with posttraumatic stress and functional ability measures. Future research should take into consideration that a Clinical Interview (Kaplan & Saccuzzo, 2013), in addition to the WHODAS.2.0 and the IES-Total could reduce possible measurement error.

A gold standard for clinical interviews is the Structured Clinical Interview for DSM-V, otherwise known as SCID (Kaplan & Saccuzzo, 2013). This Semi-Structured Interview guide allows clinicians to assess an individual's clinical and demographic variables. Using a clinical interviewing method, allows clinicians to have a deeper biopsychosocial understanding of the participant and allows a clinician to assess an individual's general affect, behaviour, willingness, or resistance to share.

Psychological status such as stress, anxiety and depression could be assessed using Clinical Diagnostic Interviews in addition to a checklist (Kaplan & Saccuzzo, 2013). This form of assessment usually takes around two and a half hours to complete (Kaplan & Saccuzzo, 2013), and therefore, may not be practical for participants experiencing fatigue and poor concentration (symptoms often seen among individuals post-mTBI). Additionally, clinicians who administer the interviewing must develop an awareness of the various sources of error or potential bias in data from interviews (Kaplan & Saccuzzo, 2013). These sources can include, cultural bias, the halo effect (confirming initial impression throughout the interview), and general standoutishness (judging one noticeable characteristic thus affecting general objectivity). Overall, Clinical Diagnostic Interviewing is effective, and has been found to be both reliable and valid although is time consuming (Kaplan & Saccuzzo, 2013).

The Structured Interview for PTSD (SI-PTSD) assesses 17 PTSS including survival and behavioural guilt (Davidson et al., 1990). The clinician assigns a severity rating that reflects both frequency and intensity of the symptoms (Davidson et al., 1990). In addition, this interview requires 20-30 minutes to administer, which is an attractive timeframe but is outdated. Alternatively, a more recent and rigorous interview is the Clinician-Administered PTSD Scale for DSM-5 (CAPS-5). This interview includes 30 items and is considered the gold standard measure which can be used onwards from one week of sustained trauma (Weathers et al., 2018). The CAPS-5 assesses 20 DSM-5 PTSS (Weathers et al., 2018). Questions target the onset and duration of symptoms, subjective distress, impact of symptoms on social and occupational functioning, improvement in symptoms since a previous CAPS administration, overall response validity, overall PTSD severity, and specifications for the dissociative subtype (depersonalization and derealization) (Weathers et al., 2018). CAPS-5 requires approximately 45-60 minutes to

administer and is considered a valid and reliable measure enabling a clinician to attain a comprehensive understanding of an individual's overall symptom presentation. CAPS-5 can also be utilised to assess for fear avoidance but cannot be solely used for this purpose. There appears to be no Structured Interview available for assessing fear avoidance. Consequently, the FAB-TBI remains the better option. Likewise, there appears to be no Structured Interviews available to assess psychological flexibility. Although questions about adaptability, acceptance, values, perspectives defusion and so forth can be attained through ascertaining demographic and clinical information.

Finally, the AAQ-ABI, measures one facet of psychological flexibility, reactive avoidance, when in fact there are several facets of psychological flexibility. They include acceptance (experiential avoidance, cognitive defusion (fusion), self as context (attachment to conceptualised self), committed action (inaction, impossibility, avoidance), values (lack of values, clarity), and contact with the present moment (conceptualised past and feared future) (Scott et al., 2016c; Hayes et al., 2011). Consequently, future research would benefit from examining the relationship between psychological flexibility and mTBI recovery outcomes using more thorough measures of psychological flexibility such as the Multidimensional Psychological Flexibility Index (Rolffs et al., 2018) or the Personalised Psychological Flexibility Index (Kashdan et al., 2020).

12. Future Research

Considering literature in this field is limited, further research is imperative. This is the first study (known to the author) which has investigated the roles of psychological flexibility and fear avoidance on the development of PTSS in a mTBI population. Future studies should consider monitoring the changes of symptoms using a longitudinal

methodology and including: one, a more ethnically diverse population and two, recruiting individuals from the general population who have sustained recent mTBI.

It is important to build on the existing findings of this study. Psychological flexibility appears to be a significant psychological mechanism in the recovery of mTBI. Further understanding how psychological flexibility helps develop and maintain negative outcomes such as PCS is imperative to inform future treatment interventions. A point of interest is that pre-injury mental health a known predisposing risk factor for PTSD and PCS was not found to be significant in this study. In addition, individuals with lower levels of psychological flexibility often experience psychopathologies (Kasdan & Rottenberg, 2010). Therefore, this association may benefit from further research. For example, a future study could use a comparative approach, assessing the impact of psychological flexibility and fear avoidance in those with and without a previous mental health history. This would provide more insight into the association and mediation between psychological flexibility and fear avoidance with pre-injury mental health on PTSS and mTBI outcome (PCS and functional status). Understanding this connection would provide further knowledge and insight into understanding how psychological flexibility and fear avoidance contribute to negative outcomes post-mTBI.

Furthermore, there are numerous important questions to ask as a result of this study. Firstly, why does psychological flexibility more so than fear avoidance mediate mTBI outcomes regarding PCS? This is particularly interesting as fear avoidance has a similar symptom presentation to PTSS and as an independent mechanism does affect PCS and functional status. Furthermore, the results showed that PTSS had a considerable effect on PCS and functional status post-mTBI. Given this finding, this association should be further examined by replicating this study and examining the mediation between

psychological flexibility and fear avoidance on the relationship of PTSS and outcomes, albeit with a larger population.

Secondly, age is relevant to the development of PPCS as stated by Rickards et al. (2020). Therefore, future research should examine psychological mechanisms on the development of PTSS post-mTBI among children and adolescence. Examining the younger population would prevent the vastly growing socio-economic backlash of PPCS on society. Additionally, by providing interventions among the younger cohorts would then mitigate potential long-term psychological disorders and costs.

Future research should also consider doing a comparative study between female and males, considering gender is a significant variable. This would provide a comprehensive understanding on how psychological mechanisms differ between sexes. Females have been noted to have higher levels of psychological flexibility and resilience (Mwangi & Ireri, 2017; Swannell, 2020; Sullivan et al., 2016; Isaacs, 2014), however, are at a greater risk of PCS. It may be possible that other biological mechanisms are at play such as hormones (Wunderle et al., 2014; Gallagher et al., 2018), and weaker neck structures (in comparison to males) (Resch et al., 2017). There is limited research regarding the sex differences in mTBI severity, recovery, and outcomes. What is available has not been thoroughly evaluated. Consequently, future research would benefit from identifying reasons for why females are at a greater risk of mTBI and adverse effects. This would provide clinicians with insight to see how gender is impacted differently and for choosing appropriate treatment options.

Lastly, considering PTSD can occur from the context of the mTBI sustained (through violence, accidents etc.,), it may be worthwhile to compare individuals who sustained a mTBI in a traumatic accident and those who sustained a mTBI as a result of a

less traumatic event. For example, a future study could compare athletes who sustained an mTBI in a sports related injury, in comparison to individuals who experienced an mTBI from a car accident (typically being much more traumatic). Brassil & Salvatore (2018) investigated the presence and frequency of PTSS in post-concussed (PC) athletes compared to a group of healthy control (HC) athletes and found that athletes who reported no PTSS prior to sports related mTBI do exhibit symptoms of PTSD. This finding suggests that even in the presence of non-traumatic mTBI, PTSS is still possible. Differing the contexts in which an mTBI is sustained could provide more insight into how PTSS are developed, whether through the environment or through more biological changes. The mediating effects of psychological flexibility and fear avoidance would then be examined in relation to PTSS and outcomes.

Chapter Six: Conclusion

Much remains to be learned about mTBI and the factors that contribute to the development of PPCS. However, there is strong evidence indicating that psychological factors impact mTBI outcomes. Likewise, medical history, stress, gender, and depression also appear to be significant risk factors within the mTBI population. This study contributes to this growing awareness, by illustrating that PTSS significantly contribute to mTBI outcomes by increasing PCS and decreasing functional status.

In addition, psychological flexibility and fear avoidance were found to significantly contribute to the development of PTSS and influence the relationship between PCS and functional status. However, when modelled simultaneously, psychological flexibility had a significant mediating role on the relationship between PTSS and PCS whereas fear avoidance did not. The present findings suggest that psychological flexibility and fear avoidance may be important psychological mechanisms in the development of PTSS following mTBI. Targeting psychological flexibility and fear avoidance has the potential to improve outcomes and overall wellbeing in individuals recovering from an mTBI and should be considered in treatment interventions.

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Chapter Eight: Appendices

Appendix A: Participant Information Sheet

Participant Information Sheet

Study title:	**The Role of Psychological Flexibility in Recovery Following Concussion**		
Locality:	**Wellington**	Ethics committee ref.:	**20/32**
Lead investigators:	**Alice Theadom and Josh Faulkner**	Contact phone number:	**0212460728**

You are invited to take part in a study looking at what impacts recovery following a concussion. Whether or not you take part is your choice. If you don't want to take part, you don't have to give a reason, and it won't affect the care you receive. If you do want to take part now, but change your mind later, you can pull out of the study at any time.

This Participant Information Sheet will help you decide if you'd like to take part. It sets out why we are doing the study, what your involvement would look like, what the benefits and risks to you might be, and what would happen after the study ends. We will go through this with you and answer any questions you may have. You do not have to decide today whether or not you will take part in this study. Before you decide you may want to talk about the study with other people, such as family, whānau, friends, or healthcare providers. Feel free to do this.

We will contact you within 30 days of receiving this information to discuss if you want to be involved.

If you agree to take part in this study, you will be asked to give consent electronically via email or text message. You will be given a copy of both this Information Sheet and the Consent Form to keep.

This document is 6 pages long, including the Consent Form. Please make sure you have read and understood all the pages.

WHAT IS THE PURPOSE OF THE STUDY?

Our overall aim is to better understand what impacts recovery following a concussion. By understanding this, we hope to improve the care and treatment for people who are recovering from a concussion.

This study is funded by the Health Research Council of New Zealand.

WHAT WILL MY PARTICIPATION IN THE STUDY INVOLVE?

You have been invited to partake in this study because you have had a concussion and have been referred to Proactive4Health Concussion Services covered by ACC.

If you would like to take part in this study, we will ask you to complete a series of questionnaires. These questionnaires can either be completed electronically and you will be sent a link via email, or via telephone depending on what you prefer. You will be asked questions about your post-concussion symptoms, how you have been feeling, as well as your ability to take part in everyday activities. At three and six months after this meeting, we will also ask you to complete these questionnaires again. Again, this will occur either via email, or by telephone.

You can ask any questions you may have about the study. If you are happy to take part, you will be asked to provide consent electronically via email or a text message

WHAT ARE THE POSSIBLE BENEFITS AND RISKS OF THIS STUDY?

Taking part in this study will take some of your time and we estimate that this will take 30 minutes. There are no known risks caused by this study, however you may feel uncomfortable or embarrassed by some questions. You do not have to answer any questions you do not wish to. All our researchers have received training in interpreting these questionnaires.

If any concerns about your well-being occur during the study, then these will be discussed with you. We can also give you the contact numbers for support services and will make a referral to your family GP for you. If there are concerns that you or others are in immediate danger of harm, we will support your/their safety by phoning the emergency services (111) or the Crisis Assessment Team. As long as it is safe to do so, this phone call will be made while we are with you.

Your usual care under concussion services will not be affected in any way by being involved in the study or withdrawing from the study at any stage. Your involvement in this study will be stopped should there be any harmful effects or if the doctor or other medical professionals, feel it is not in your best interests to continue.

WHO PAYS FOR THE STUDY?

There should be no direct costs to you in taking part in this study. We will provide you with a $20 food voucher to compensate for your time.

WHAT IF SOMETHING GOES WRONG?

It is unlikely that you will be at risk of harm from taking part in this study. If something goes wrong, please contact the principal investigator as soon as possible 09 921 9999 x7805

WHAT ARE MY RIGHTS?

The study files and all other information that you provide will remain strictly confidential, unless there is information that indicates you, your child or someone else is at risk.

No material that could personally identify you will be used in any reports or discussions about this study.

Your participation is entirely your choice, and you will be able to withdraw from the study at any time without experiencing any disadvantage.

You will be able to access your information collected as part of the study if you wish to do so. If any information that may be of benefit to you is found during the study, we will contact you to let you know

WHAT HAPPENS AFTER THE STUDY OR IF I CHANGE MY MIND?

When the study is finished, your records will be stored on a computer by the lead investigator Professor Theadom). All computer records will be password protected. No information will be shared outside of the research team without seeking your permission.

After 10 years all electronic information will be deleted, and paper forms will be shredded and destroyed with the university confidential waste.

After we have looked at all the data, we will send you a summary of results if you would like to receive them.

WHO DO I CONTACT FOR MORE INFORMATION OR IF I HAVE CONCERNS?

If you have any questions, concerns or complaints about the study at any stage, you can contact:

Alice Theadom
Telephone number: 09 921 9999 x7805
Email: alice.theadom@aut.ac.nz

If you concerns regarding the conduct of the research then notify Dr Carina Meares, Executive Secretary of AUTEC, *ethics@aut.ac.nz* , (+649) 921 9999 ext 6038.

If you want to talk to someone who isn't involved with the study, you can contact an independent health and disability advocate on:

Phone : 0800 555 050
Fax : 0800 2 SUPPORT (0800 2787 7678)
Email : advocacy@hdc.org.nz

You can also contact the health and disability ethics committee (HDEC) that approved this study on:

Phone: 0800 4 ETHICS
Email: hdecs@moh.govt.nz

Support Services available:

The Brain Injury Association
Phone: (04) 473 5004
Address: Federation House, Level 2/9599, Molesworth St, Thorndon

Maori Community Health Team:
Phone: (04) 237 9608
Address: 213/217 Bedford St Cannons Creek Porirua 5024

Te Haika: Crisis Assessment Team
Phone: 0800 745 477

Please keep this for your information.
Thank you for interest in this study

Appendix B: The Depression, Anxiety and Stress Scale-21 (DASS-21)

DASS 21 NAME _____ DATE _____

Please read each statement and circle a number 0, 1, 2 or 3 which indicates how much the statement applied to you over the past week. There are no right or wrong answers. Do not spend too much time on any statement.

The rating scale is as follows:

0 Did not apply to me at all - NEVER

1 Applied to me to some degree, or some of the time - SOMETIMES

2 Applied to me to a considerable degree, or a good part of time - OFTEN

3 Applied to me very much, or most of the time - ALMOST ALWAYS

		N	S	O	AA	FOR OFFICE USE D	A	S
1	I found it hard to wind down	0	1	2	3			
2	I was aware of dryness of my mouth	0	1	2	3			
3	I couldn't seem to experience any positive feeling at all	0	1	2	3			
4	I experienced breathing difficulty (eg, excessively rapid breathing, breathlessness in the absence of physical exertion)	0	1	2	3			
5	I found it difficult to work up the initiative to do things	0	1	2	3			
6	I tended to over-react to situations	0	1	2	3			
7	I experienced trembling (eg, in the hands)	0	1	2	3			
8	I felt that I was using a lot of nervous energy	0	1	2	3			
9	I was worried about situations in which I might panic and make a fool of myself	0	1	2	3			
10	I felt that I had nothing to look forward to	0	1	2	3			
11	I found myself getting agitated	0	1	2	3			
12	I found it difficult to relax	0	1	2	3			
13	I felt down-hearted and blue	0	1	2	3			
14	I was intolerant of anything that kept me from getting on with what I was doing	0	1	2	3			
15	I felt I was close to panic	0	1	2	3			
16	I was unable to become enthusiastic about anything	0	1	2	3			
17	I felt I wasn't worth much as a person	0	1	2	3			
18	I felt that I was rather touchy	0	1	2	3			
19	I was aware of the action of my heart in the absence of physicalexertion (eg, sense of heart rate increase, heart missing a beat)	0	1	2	3			
20	I felt scared without any good reason	0	1	2	3			
21	I felt that life was meaningless	0	1	2	3			
					TOTALS			

DASS Severity Ratings

The DASS is a **quantitative** measure of distress along the 3 axes of depression, anxiety[1] and stress[2]. It is not a categorical measure of clinical diagnoses.

Emotional syndromes like depression and anxiety are intrinsically dimensional - they vary along a continuum of severity (independent of the specific diagnosis). Hence the selection of a single cut-off score to represent clinical severity is necessarily arbitrary. A scale such as the DASS can lead to a useful assessment of **disturbance**, for example individuals who may fall short of a clinical cut-off for a specific diagnosis can be correctly recognised as experiencing considerable symptoms and as being at high risk of further problems.

However for clinical purposes it can be helpful to have 'labels' to characterise degree of severity relative to the population. Thus the following cut-off scores have been developed for defining mild/moderate/severe/ extremely severe scores for each DASS scale.

Note: the severity labels are used to describe the full range of scores in the population, so 'mild' for example means that the person is above the population mean but probably still way below the typical severity of someone seeking help (ie it does not mean a mild level of disorder.

The individual DASS scores do not define appropriate interventions. They should be used in conjunction with all clinical information available to you in determining appropriate treatment for any individual.

[1]Symptoms of psychological arousal
[2]The more cognitive, subjective symptoms of anxiety

DASS 21 SCORE

DEPRESSION SCORE	ANXIETY SCORE	STRESS SCORE

	Depression	Anxiety	Stress
Normal	0 - 4	0 - 3	0 - 7
Mild	5 - 6	4 - 5	8 - 9
Moderate	7 - 10	6 - 7	10 - 12
Severe	11 - 13	8 - 9	13 - 16
Extremely Severe	14 +	10 +	17 +

Appendix C: Impact of Events Scale-Revised (IES-R)

The Impact of Event Scale - Revised (IES-R)

Instructions:

Below is a list of difficulties people sometimes have after stressful life events. Please read each item, and then indicate how distressing each difficulty has been for you DURING THE PAST SEVEN DAYS with respect to (the event). How much were you distressed or bothered by these difficulties?

		Not at all	A little bit	Moderately	Quite a bit	Extremely
1	Any reminder brought back feelings about it	0	1	2	3	4
2	I had trouble staying asleep	0	1	2	3	4
3	Other things kept making me think about it	0	1	2	3	4
4	I felt irritable and angry	0	1	2	3	4
5	I avoided letting myself get upset when I thought about it or was reminded of it	0	1	2	3	4
6	I thought about it when I didn't mean to	0	1	2	3	4
7	I felt as if it hadn't happened or wasn't real	0	1	2	3	4
8	I stayed away from reminders about it	0	1	2	3	4
9	Pictures about it popped into my mind	0	1	2	3	4
10	I was jumpy and easily startled	0	1	2	3	4
11	I tried not to think about it	0	1	2	3	4
12	I was aware that I still had a lot of feelings about it, but I didn't deal with them	0	1	2	3	4
13	My feelings about it were kind of numb	0	1	2	3	4
14	I found myself acting or feeling as though I was back at that time	0	1	2	3	4
15	I had trouble falling asleep	0	1	2	3	4
16	I had waves of strong feelings about it	0	1	2	3	4

	Not at all	A little bit	Moderately	Quite a bit	Extremely
17 I tried to remove it from my memory	0	1	2	3	4
18 I had trouble concentrating	0	1	2	3	4
19 Reminders of it caused me to have physical reactions, such as sweating, trouble breathing, nausea, or a pounding heart	0	1	2	3	4
20 I had dreams about it	0	1	2	3	4
21 I felt watchful or on-guard	0	1	2	3	4
22 I tried not to talk about it	0	1	2	3	4

Appendix D: Acceptance and Action Questionnaire-Acquired Brain Injury (AAQ-ABI)

Reactive Avoidance (RA)

Acceptance and Action Questionnaire Concussion (AAQ-C)

Read each sentence. Then, circle a number between 0-4 that tells how true each sentence is for you

	Not at all true	A little true	Pretty true	True	Very True
1. I hate how my concussion makes me feel about myself	0	1	2	3	4
2. I need to get rid of my anxiety about my concussion	0	1	2	3	4
3. I stop doing things when I feel scared about my concussion	0	1	2	3	4
4. My concussion defines me as a person	0	1	2	3	4
5. I am moving forward with my life	0	1	2	3	4
6. I would give up important things in my life if I could make the concussion go away	0	1	2	3	4
7. My worries and fears about my concussion are true	0	1	2	3	4
8. Other people make it hard for me to accept myself	0	1	2	3	4
9. Most people are doing better than me	0	1	2	3	4

111112

Scoring

Reverse item 5 and then add all items giving a range of scores between 0-36. Higher scores are indicative of greater psychological inflexibility (to maintain consistency with the scoring of the AAQ-II).

ABI population Mean = 12.61 (SD = 9.32), see reference below for additional psychometric properties of the scale and comparison to the AAQ-II:

Whiting, DL, Deane, FP, Ciarrochi, J, McLeod, HJ, Simpson, GK. Validating measures of psychological flexibility in a population with Acquired Brain Injury. *Psychological Assessment*, Nov 24, 2014, No Pagination specified. http://dx.doi.org/10.1037/pas0000050

Appendix E: Fear Avoidance Behaviour after Traumatic Brain Injury Questionnaire (FAB-TBI)

Participant ID: _____ **Date:** _____

Instruction: Please rate how much you agree with each of these statements as they apply to you over the past month.

		Strongly disagree	Disagree	Agree	Strongly Agree
1	I have put parts of my life on hold.				
2	I have avoided my usual activities.				
3	I cannot do activities which (might) make my symptoms worse				
4	My work might harm my brain.				
5	I should not do my normal work with my present symptoms.				
6	My head pain is telling me that I have something dangerously wrong.				
7	I worry that when I have to think or concentrate too hard that I will bring on a headache.				
8	My headaches put my head and brain at risk for the rest of my life.				
9	I purposely avoid doing activities that might elicit a headache.				
10	I'm afraid that I might make my headache pain worse by concentrating too much or being too mentally active.				
11	I wouldn't have this much pain if there weren't something potentially dangerous going on in my head.				
12	I avoid external reminders of a stressful experience (for example, people, places, conversations, activities, objects, or situations).				
13	I stop what I am doing when my symptoms start to get worse.				
14	If I know that something will make my symptoms worse I don't do it anymore.				
15	Because of my symptoms most days I spend more time resting than doing activities.				
16	Most days my symptoms keep me from doing much at all.				

Version: January 10, 2018

Appendix F: Rivermead Post-Concussion Symptom Questionnaire (RPQ)

The Rivermead Post-Concussion Symptoms Questionnaire*

After a head injury or accident some people experience symptoms which can cause worry or nuisance. We would like to know if you now suffer from any of the symptoms given below. As many of these symptoms occur normally, we would like you to compare yourself now with before the accident. For each one, please circle the number closest to your answer.

0 = Not experienced at all
1 = No more of a problem
2 = A mild problem
3 = A moderate problem
4 = A severe problem

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

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

Are you experiencing any other difficulties?

1. _____	0	1	2	3	4
2. _____	0	1	2	3	4

*King, N., Crawford, S., Wenden, F., Moss, N., and Wade, D. (1995) J. Neurology 242: 587-592

06/23/08

Appendix G: World Health Organization Disability Assessment Schedule (WHODAS 2.0)

WHODAS 2.0

WORLD HEALTH ORGANIZATION
DISABILITY ASSESSMENT SCHEDULE 2.0

12-item version, self-administered

This questionnaire asks about difficulties due to health conditions. Health conditions include diseases or illnesses, other health problems that may be short or long lasting, injuries, mental or emotional problems, and problems with alcohol or drugs.

Think back over the past 30 days and answer these questions, thinking about how much difficulty you had doing the following activities. For each question, please circle only one response.

In the past 30 days, how much difficulty did you have in:						
S1	Standing for long periods such as 30 minutes?	None	Mild	Moderate	Severe	Extreme or cannot do
S2	Taking care of your household responsibilities?	None	Mild	Moderate	Severe	Extreme or cannot do
S3	Learning a new task, for example, learning how to get to a new place?	None	Mild	Moderate	Severe	Extreme or cannot do
S4	How much of a problem did you have joining in community activities (for example, festivities, religious or other activities) in the same way as anyone else can?	None	Mild	Moderate	Severe	Extreme or cannot do
S5	How much have you been emotionally affected by your health problems?	None	Mild	Moderate	Severe	Extreme or cannot do

Please continue to next page...

WHODAS 2.0
WORLD HEALTH ORGANIZATION
DISABILITY ASSESSMENT SCHEDULE 2.0

12
Self

In the past 30 days, how much difficulty did you have in:						
S6	Concentrating on doing something for ten minutes?	None	Mild	Moderate	Severe	Extreme or cannot do
S7	Walking a long distance such as a kilometre [or equivalent]?	None	Mild	Moderate	Severe	Extreme or cannot do
S8	Washing your whole body?	None	Mild	Moderate	Severe	Extreme or cannot do
S9	Getting dressed?	None	Mild	Moderate	Severe	Extreme or cannot do
S10	Dealing with people you do not know?	None	Mild	Moderate	Severe	Extreme or cannot do
S11	Maintaining a friendship?	None	Mild	Moderate	Severe	Extreme or cannot do
S12	Your day-to-day work?	None	Mild	Moderate	Severe	Extreme or cannot do

H1	Overall, in the past 30 days, how many days were these difficulties present?	***Record number of days*** ____
H2	In the past 30 days, for how many days were you totally unable to carry out your usual activities or work because of any health condition?	***Record number of days*** ____
H3	In the past 30 days, not counting the days that you were totally unable, for how many days did you cut back or reduce your usual activities or work because of any health condition?	***Record number of days*** ____

This completes the questionnaire. Thank you.