From the Laboratory to the Community: A Study Exploring Factors to Make Exercise for Persistent Post-concussion Symptoms More Accessible.

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Abstract

The overarching aim of this research program was to evaluate the effectiveness of exercise rehabilitation for persistent post-concussion symptoms (PPCS), including if it can be applied in a general (non-athlete) population. This aim was explored by firstly identifying exercise parameters shown to have beneficial effects on PPCS recovery. Then, how participation in exercise programs might be affected by general knowledge of concussion, and other individual factors such as attitudes and beliefs was investigated. By examining the current evidence in the exercise for PPCS literature and exploring individual factors that can affect rehabilitation decisions, it was expected that new avenues might be identified to make exercise rehabilitation for PPCS more acceptable, accessible, and effective for the community.

Study 1 was a systematic review to identify a set of clearly defined exercise parameters that has proven effective in high-quality post-concussion intervention studies (*n*=8). This review found support for programs that commence after an initial period of rest for 24-48 hours, and then progress to aerobic exercise for at least 4 times a week, for 10-15 minutes each time, and at an intensity of 50% HR of the sub-symptom threshold, for up to 4 weeks or feeling asymptomatic (whichever came earlier). Considering that most studies in this review tested aerobic exercise for adolescents and athletes in relatively supported rehabilitation contexts, the specification of the parameters represent a conservative interpretation of the settings required to effect change in other populations (e.g., the shortest effective program duration). Further research on these recommended parameters is essential to determine if such programs can deliver benefits to a wider demographic. Importantly, the identification of these evidence-based parameters provides a much-needed benchmark that could stimulate further discussion of the design and delivery of PPCS exercise interventions that are more accessible to the community.

Study 2 explored the knowledge and attitudes about concussion and evidence-based rehabilitation in an Australian community sample (*n* = 224). The study used an exploratory design, *t* tests and correlation analysis to determine if there were any differences in knowledge and attitude towards concussion and rehabilitation between important demographic data (e.g., gender, concussion history, contact sports participation). It was found that while knowledge and attitudes were higher than average in the overall sample, common misconceptions about risks of repeated injuries, prolonged symptoms and a perception that athletes held riskier attitudes towards concussion persisted. Only about 2% of the sample suggested exercise or made references suggestive of physical activity as a possible rehabilitation option. The findings from this study can be useful to address common gaps in concussion education programs and encourage the need to include information on active evidence-based rehabilitation in such programs for both athletes and the wider community.

Study 3 investigated individual sociocognitive factors (i.e., theory of planned behaviour) that could affect decisions to participate in PPCS exercise rehabilitation in an Australian community sample (*n* =459). Using structured equation modelling, this study identified the predictive utility of sociocognitive factors (i.e., *attitudes, subjective norms, perceived behavioural control)* on the *intention* to participate in a PPCS exercise rehabilitation program. The study found that *subjective norms* (i.e., what significant others thought about exercise rehabilitation) were the strongest significant predictor of *intention* to participate in exercise rehabilitation. *Perceived behavioural control* was also a significant predictor of *intention* but not *attitudes*. While generally positive *attitudes* towards PPCS exercise rehabilitation were observed, it did not translate to people's *intention* to participate in such a program. The findings from this study could be useful to shift misinformed attitudes, design exercise programs that give people more control over their decisions and harness the influence of significant others when promoting future exercise rehabilitation programs.

Together, this research program was used to evaluate if exercise could be an effective PPCS rehabilitation option for the general community, and if so, the form that it might take; and how such a program could be made more viable and accessible by addressing end-user knowledge gaps and decision-making factors. This research has shown that exercise-only PPCS interventions with certain characteristics are effective in a limited demographic. It is possible but not yet known if such interventions could benefit a wider demographic. For successful community adoption, the next steps will require investigation of programs designed according to the proposed exercise parameters, and efforts to address and shape knowledge and attitude gaps about exercise rehabilitation for PPCS through education programs.

Keywords

Persistent post-concussion symptoms; concussion; mild traumatic brain injury; exercise; exercise rehabilitation; knowledge; attitudes; subjective norms; perceived behavioural control; knowledge translation; exercise parameters; theory of planned behaviour.

List of Presentations and Achievements

Jaganathan, K.S. (2019). *Does Active-TBI improve outcomes in adults after mild traumatic brain injury? A protocol for a randomised control trial.* IHBI Inspires 2019 Annual Conference, Brisbane, Australia, 12-13 Aug 2019.

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Jaganathan, K.S. (2019). *Does Active-TBI improve outcomes in adults after mild traumatic brain injury? A protocol for a randomised control trial*. Talk given at the Queensland, Australian Psychological Society College of Clinical Neuropsychologists event, 4 Sep 2019.

Jaganathan, K.S. (2020). An inclusive recruitment strategy can help to improve mTBI research. Published abstract. Proceedings of the 40th National Academy of Neuropsychology Conference, Chicago, USA, 14-16 Oct 2020

Sullivan, K.A., Kinmond, S.C.R., **Jaganathan, K.S.** (2021). Public misconceptions about concussion are not improved by standard post-injury advice. Published abstract. Proceedings of the 40th National Academy of Neuropsychology Conference, Washington, D.C., USA, 10-13 Nov 2021.

Jaganathan, K.S. (2019, November). Tutor of the Year, Queensland University of Technology, Faculty of Health, Brisbane, Australia.

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Sullivan, K.A., **Jaganathan, K.S**., & Kinmond S. (in press). Sports fans, wagering, and concussion knowledge: Implications for injury nondisclosure. *Brain Impairment.*

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List of Abbreviations

ANS	Autonomic nervous system
BDNF	Brain-derived neurotrophic factor
CBF	Cerebral blood flow
DSM	Diagnostic and statistical manual of mental disorders
fMRI	Functional magnetic resonance imaging
HR	Heart rate
ICD	International Classification of Diseases
mTBI	Mild traumatic brain injury
PCS	Post-concussion symptoms
PPCS	Persistent post-concussion symptoms
RTP	Return to play
SRC	Sports related concussion
TPB	Theory of planned behaviour

Preface

The Office of Research Ethics and Integrity at Queensland University of Technology approved the ethics for this research (Approval # 1900000328/2000000355; see Appendix A). The format of this thesis combines guidelines prescribed by the American Psychological Association (7th edition) and the thesis template for a thesis by monograph provided by Queensland University of Technology. All statistical analyses were conducted using IBM Statistical Package for Social Sciences (SPSS), version 27 and IBM SPSS AMOS version 26.

The original scope of this research program was amended in 2020 because of the Covid-19 pandemic. Studies 2 and 3 were designed to collect data from participants using online surveys due to government mandated lockdowns that made any face-to-face contact or initially planned supervised exercise studies impossible.

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Chapter 1: Introduction

This chapter presents an overview of this thesis. Section 1.1 introduces the research problem. A background to this research will be presented in Section 1.2. Section 1.3 will outline the conceptual frameworks central to this thesis. Section 1.4 highlights the significance of this research program and how it can contribute to current theory and practice. Section 1.5 defines the aim of this research program. Section 1.6 outlines the scope of this thesis. Section 1.7 is an overview of the structure of this thesis which is formatted to meet the requirements of a thesis by monograph under Queensland University of Technology (QUT) guidelines. Section 1.8 will conclude the chapter with a summary.

1.1 Research Problem

In 2018, Liverpool played Real Madrid in the Champion's League Final. Just after the second half commenced, Liverpool goalkeeper Loris Karius suffered a head collision with an opponent. Three minutes later, under little pressure, he threw the ball onto the feet of an opponent, which enabled the opponent to score. A while later, he allowed a shot to slip through his gloves, and Liverpool lost the match. Nine days following the game, medical professionals confirmed that Karius had sustained a concussion in the 48th minute of the match (White et al., 2020). The disorientation and misjudgement observed in him for the rest of the match were concluded to be the consequences of post-concussion symptoms (PCS).

The preceding scenario is used to set the context for some of the questions this thesis will investigate. In the scenario, it is unclear why Karius was not removed from play, what exactly was done to determine if a concussion had occurred, how reliable an assessment to identify potential cognitive deficits could have been and if anything was done to help with his recovery. Further, as argued by White et al. (2020), media commentary during the incident trivialised and deflected from the severity of the concussion, highlighting the potential influence this could have on viewers' perceptions on concussion and possible consequences after such an injury. Apart from a handful of studies that investigated Karius' case, there were no specific details reported on how long Karius suffered from symptoms and what was done to help him recover. While it is not possible to ascertain why management of the injury was inconsistent with sports management guidelines that recommend removal of a player after a concussion, the incident can shed some light on how knowledge about concussion and managing potential symptoms can be crucial. Sports-related concussion may seem to be the most common cause of injury given the exposure through media broadcasting, but such injuries can also occur through non-sports related causes. This makes concussion and the onset of persistent post-concussion symptoms (PPCS) in some individuals a problem that can affect both athletes and the wider community.

Persistent post-concussion symptoms are an array of physical, cognitive, and emotional symptoms that can result in functional impairment after a mild traumatic brain injury (mTBI) or concussion[1]. A concussion can be caused by events or activities such as contact sports participation, assaults, falls or motor vehicle accidents. While most individuals recover within two weeks of a concussion (Belanger et al., 2005; Binder et al., 1997; Carroll, Cassidy, Peloso, et al., 2004), PPCS can affect up to 10-50% of individuals post-injury (Iverson et al., 2013; Muelbl et al., 2018; Rutherford et al., 1979).

PPCS can lead to considerable disruption to work, sports participation and other areas of functioning. It has been found that between a quarter to half of the people who experience PPCS can report four or more symptoms in various domains up to one year after a concussion (McMahon et al., 2014; Polinder et al., 2018; Røe et al., 2009; Scheenen et al., 2017) with some studies reporting persistent cognitive problems in people for up to seven years after an injury (Rona et al., 2020; Theadom, Starkey, et al., 2018). It is therefore important that people

[1] mTBI and concussion are terms used interchangeably in the literature although there are some distinctions between these terms. These differences in terminology are discussed in Chapter 2. For consistency, the rest of this chapter will use the term "concussion".

suffering from PPCS are given information about symptom management and get the required help with symptoms across multiple domains. However, there is yet to be a consensus on evidence-based rehabilitation to hasten recovery, reduce sequelae, or ameliorate long-term deficits in those affected (Kurowski et al., 2016; Yuan et al., 2017).

Current best practice in PPCS rehabilitation focuses on providing education and psychological therapies (e.g., cognitive behavioural therapy; Al Sayegh et al., 2010; Moore et al., 2017; Sullivan et al., 2020); but exercise is emerging as a promising option with benefits observed in symptoms across domains. The past decade has seen an increase in small-scale studies supporting the benefits of exercise to treat PPCS. Exercise under controlled conditions has been tested on limited populations (e.g., primarily collegiate athletes), and is becoming accepted as safe and effective to treat PPCS (Gagnon et al., 2016; Kurowski et al., 2017; Leddy et al., 2013). Extended benefits of exercise such as physical conditioning after an injury, improved physical and mental health, and the positive effects on a wider range of symptoms makes exercise an appealing option. However, most of the literature reporting positive findings are based on studies that have combined exercise as part of a multimodal approach. Such approaches make it difficult to identify specifically how exercise works to alleviate PPCS (Adams & Moore, 2017). Further research is needed to identify studies using only exercise rehabilitation. While research on such unimodal studies is sparse, this body of research is growing. Distilling a set of clearly defined parameters from existing literature may be beneficial for further replication of PPCS rehabilitation studies. Undertaking such studies that evaluate the efficacy of specific exercise parameters would be an important step taken towards the development of clearer recommendations on exercise protocols for PPCS.

For all its suggested benefits in the literature, and the promising results from the small-scale trials conducted to date, exercise rehabilitation for PPCS is still lacking large scale studies evaluating its efficacy among wider population groups other than adolescent athletes. The latest Concussion in Sport Group (CISG) consensus statement recommends gradual and progressive activity while staying below the symptom exacerbation threshold after 24-48 hours of rest, and treatment for PPCS to consider an individualised sub-symptom exercise program (McCrory et al., 2017); but it is unclear if this advice should also apply to non-athletes. This guideline could be a practical way to support athlete recovery, given that athletes may be fitter and more conditioned to take up rehabilitative exercises than non-athletes; but as highlighted earlier, concussions are not limited to sports and PPCS can arise from other non-sports-related events or activities. While concussion management guidelines such as those from the US Department of Defence (Department of Veteran Affairs; Department of Defence, 2016) and the Ontario Neurotrauma Foundation (2018) address management of concussion in non-athletes, these guidelines only acknowledge the use of supervised graded exercise without specific details. If exercise has shown promise for PPCS rehabilitation in sports concussion, then it is important to investigate if there are any underlying reasons behind the lack of studies on exercise for wider non-athlete populations. Exploring some of the potential reasons can be useful to bring this promising rehabilitative option closer to the general community.

1.2 Research Background

PPCS is an unpredictable and diverse problem in a minority of individuals who experience concussions. This has led to people with PPCS being referred to as the "miserable minority" in some quarters (Rohling et al., 2012; Ruff et al., 1996; Shenton et al., 2012; Wood, 2004). The heterogeneity of presentations makes PPCS complex to characterise (Iverson, 2019), and it has also led to recommendations for an individualised, interdisciplinary approach towards rehabilitation (Jaganathan & Sullivan, 2020). Such approaches are considered useful for PPCS because they identify problems specific to individuals and try to adjust the therapy to solve the specific presenting problems. Several models attempt to explain the heterogeneity of PPCS after a concussion, including why only some individuals are affected. These models implicate the injury event itself (e.g., nature of injury, trauma) and individual factors both pre- and post-injury (e.g., pre-existing psychological problems, post-injury social support). While these models are useful to describe the potential aetiology of PPCS, none of the models are comprehensive enough to predict individual outcomes that are pertinent for rehabilitation planning (Silverberg et al., 2015).

Despite the challenges in characterising PPCS, the subjective and debilitating nature of the condition necessitates the need for rehabilitation that aids recovery and facilitates those affected to return to normal activities. Current management approaches have shifted from predominantly education or psychological approaches to the use of multimodal rehabilitation that combines one or more rehabilitative options depending on the needs of the individual. Such multidisciplinary rehabilitation has found to be promising in reducing symptoms and facilitating earlier return to pre-injury functioning (Bailey et al., 2019; Grabowski et al., 2017; Rytter et al., 2019; Vikane et al., 2017).

Of the various modalities used to treat PPCS, exercise is now being discussed as a "pan-domain" rehabilitation modality (Silverberg et al., 2020). This position argues that the salutary benefits of exercise for PPCS are evident across multiple domains of physical and mental health. This viewpoint may have some merit, since there is abundant support in the literature for exercise to be effective in treating psychological problems such as depression and anxiety (Tomasi et al., 2019), sleeping problems (Singh et al., 1997), and improving cognitive deficits (Bliss et al., 2020). These symptoms are common in people experiencing PPCS, providing some support that exercise could be a useful, multifaceted option to address concussion symptoms. While the specific mechanisms behind how exercise works for PPCS are yet to be clearly understood, both animal (Griesbach, Hovda, et al., 2004; Griesbach, Tio, et al., 2012) and human (Clausen et al., 2016; Leddy et al., 2013) studies have interpreted increases in cerebral blood flow (CBF), release of brain-derived neurotrophic factor (BDNF) and restoration of autonomic nervous system (ANS) dysregulation to be some potential reasons. Further, exercise has also been shown to enhance neuroplasticity, and this ability for the brain to heal itself, could potentially be how exercise alleviates PPCS (Haider et al., 2020; Leddy, Haider, et al., 2018).

Compared to other emerging therapies for PPCS, such as transcranial magnetic stimulation (TMS; Mollica et al., 2021) or hyperbaric oxygen therapy (Harch et al., 2020), the ability for "therapeutic" exercise to be relatively simple to deliver, highly accessible, and not require complicated equipment makes it a rehabilitation option that is worth exploring further. On the back of emerging empirical support, a paradigm shift is also evident in expert advice and position statements changing tack on the management guidelines. Previous recommendations to rest till asymptomatic (McCrory et al., 2009; McCrory et al., 2013) have now been replaced by gradual resumption of light-moderate activity that could be beneficial after an acute period of rest for longer than 48 hours (Collins et al., 2016; McCrory et al., 2017; Silverberg & Iverson, 2013).

A unique aspect of exercise studies on PPCS rehabilitation is that they typically employ *graded sub-symptom threshold exercise* (Gagnon et al., 2009; Gagnon et al., 2016; Leddy, Haider, et al., 2018; Leddy, Haider, Ellis, et al., 2019; Leddy et al., 2010). This entails progressive exercising to a threshold just below an intensity, measured by the heart rate (HR), that causes exacerbation of symptoms. To obtain a clearer picture of how such exercise could be useful for PPCS rehabilitation, two reviews have attempted to specify the ideal exercise volume and duration for PPCS rehabilitation (Baker et al., 2020; Howell et al., 2019). However, these reviews were based on a collection of studies that included multimodal rehabilitation where exercise made up one component of more comprehensive programs. It remains extremely challenging to draw optimal exercise parameters from such reviews without the other rehabilitation modalities possibly confounding the findings. For example, it is impossible to attribute benefits of a multimodal rehabilitation program to exercise when other aspects of the program such as psychological therapy could also have played a role in recovery. While the literature has progressed to evaluate the efficacy of different combinations of multimodal rehabilitation, the ambiguity and inconsistent application of the exercise component within these programs have remained. Granted, multimodal rehabilitation is aligned to current management guidelines, but knowledge on specific exercise parameters that offer optimal benefits is still important. Establishing a clear and well-defined set of exercise parameters can be useful to streamline exercise rehabilitation, compare across studies, replicate findings, and make it more accessible to people.

It had been raised earlier that studies on PPCS exercise rehabilitation typically focus on athletes and sports concussion, whereas its efficacy in other groups is less clear. There are no studies describing an exercise program for PPCS for use by the general population or when the concussion has another (non-sport) cause. It is unclear if the medical advice to concussion patients could be influencing rehabilitation, but this is a possibility given that studies have found concussion patients to still be advised to rest for longer periods than the current recommendations of at least 48 hours (Collins et al., 2016; Silverberg & Otamendi, 2019). These findings also raised other issues such as how informed healthcare professionals are regarding management practices specific to PPCS (Knox et al., 2017). With some studies estimating that sports-related concussions make up only about 15-20% of concussions overall (Hon et al., 2019; Thomas et al., 2020b), the need to identify and offer evidence-based rehabilitation to the wider community is accentuated. If the evidence for effectiveness of exercise for PPCS shows promise, even if it is for sports concussion only, there appears to be a considerable gap in the dissemination of this advice to the public. It is expected that the literature on knowledge transfer can offer some guidance to understand and address these gaps.

Knowledge translation is the process of introducing and applying new evidence to close the gap between research and clinical practice (Jones et al., 2015). Studies exploring gaps in knowledge transfer have suggested that both healthcare providers and patients have a role to play. Knowledge translation gaps are not a new concept and have been identified in various research domains (Lean et al., 2008; Lenfant, 2003). A lapse between evidence-based research and applying it to people who need it has been highlighted in several health contexts (Lenfant, 2003). Consequently, the immense cost and effort placed in discovering useful applications in health contexts may not be achieving its ultimate purpose of clinical utility to help people. The knowledge translation process is categorised in two stages; the first being the process of applying and investigating effects of a treatment approach under lab conditions (T1); the second being the process of translating key findings and delivering it to people who need it (T2; Rubio et al., 2010). As noted in many other areas of research with such gaps, (Woolf, 2008), it appears that PPCS is also plagued with a problem where much of the resources have been expended in T1, but T2, the process of bringing evidence-based rehabilitation to people needing it is neglected. This research program seeks to identify and explore ways to bridge some of these gaps contributing towards the discrepancy between research and practice.

The interaction between several factors has been put forward as possible obstacles in moving research to practice (Rubio et al., 2010). A key factor is knowledge about a condition and potential treatment options which have shown to influence help-seeking (Mechanic & Volkart, 1960; Sirri et al., 2013). Better knowledge about an illness and its potential treatment has been shown to support active treatment seeking in patients with mental health (Tran et al., 2019), cardiac (Venkatesan et al., 2018) and cancer diagnoses (Sheikh & Ogden, 1998). The current literature is replete with studies on concussion knowledge and attitudes among athletes (e.g., Anderson et al., 2016; Manasse-Cohick & Shapley, 2013; Mannings et al., 2014; Register-Mihalik et al., 2013; Sefton, 2003), but the current state of knowledge about concussion, PPCS and rehabilitation in the general community, especially in Australia, is less clear.

Another layer of complexity in knowledge translation is gaining an understanding of what people do once they acquire the knowledge. Studies have suggested that despite having the knowledge, healthcare professionals and patients still do not apply what they know to achieve optimal health outcomes (Lenfant, 2003). This reluctance may arise from many possibilities including personal beliefs, potential risks, and other context-specific factors. For example, when patients have more positive attitudes about the treatment for mental health, this contributes towards more active treatment seeking (Mojtabai et al., 2016). Similarly, doctors may not recommend a particular treatment approach based on personal attitudes, bias or a less informed belief, resulting in a patient possibly missing out on a potentially useful treatment approach. By understanding some of the factors that could hold people back from participating in evidence based PPCS rehabilitation, it may be possible to target education efforts and devise program enhancements that will increase and support engagement in such programs (Chen et al., 2020; Tesfaye et al., 2020). Apart from personal factors, people’s choices, and potential barriers to engaging in rehabilitation can also be important considerations in the design of such programs to improve uptake (Colquhoun et al., 2017).

Exercise rehabilitation for PPCS is clearly a promising option, but for this area to advance, a systematic review of the evidence thus far is needed to identify optimal programming. While empirical evidence has encouraged a shift in the sports concussion management guidelines from a “rest-centric” approach to an “active” one that recommends the use of progressive exercise, this advice does not yet seem to have filtered down to concussion management in the general community. The knowledge transfer gaps identified earlier could be contributing to this lag in adopting a promising evidence-based practice for PPCS.

1.3 Conceptual Framework

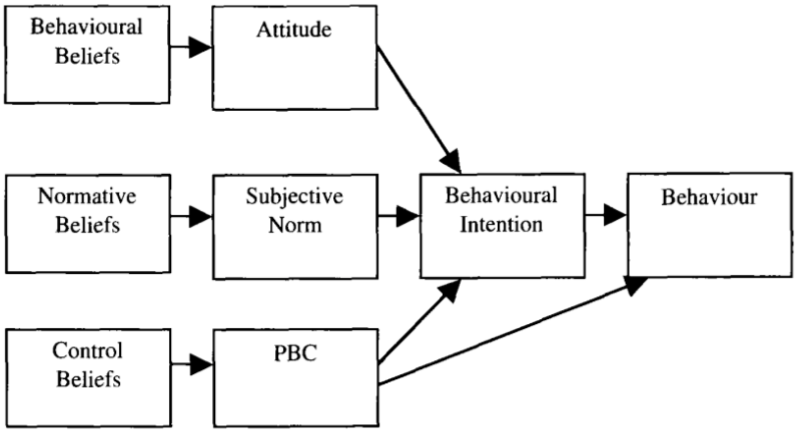
A key aim of this research program is to identify and consolidate a set of exercise principles and settings (‘parameters’) for replication and further investigation in wider population groups. The identification of such parameters from the extant literature, even if drawn from limited studies, is considered vital to guide and streamline future research in this area. To obtain a clearly definable and structured set of exercise parameters, this thesis will be guided by the exercise literature to define exercise and identify the important components of exercise that are useful for research and practice. This thesis defines exercise as “a subset of physical activity that is planned, structured, and repetitive, and has a final or an intermediate objective to improve or maintain a predetermined outcome” (Caspersen et al., 1985, p. 1). This definition has informed exercise rehabilitation literature spanning decades (Dasso, 2019; Harris et al., 2021; Södergren et al., 2008; Summerson et al., 1991).

Further, as specified by Winters-Stone et al. (2014), the following exercise parameters will be considered: *frequency, intensity, time,* and *type* of exercise (i.e., the “*FITT*” principle). The term “optimal” exercise parameters for the context of this thesis will be exercise parameters that yield beneficial outcomes in the most efficient way (e.g., shortest time, lowest intensity). Lawrence et al. (2018) proposed that exercise for PPCS should also consider the time elapsed since injury because of the existing ambiguity in this area and for this to be important for enrolment of people into exercise programs. For example, in the current CISG (McCrory et al., 2017), exercise should be stopped immediately post-injury, but after a period of time has passed (24 - 48 hours), non-contact exercise can gradually be reinstated. Studies on exercise for PPCS have also included a wide range of participants from those exercising within days after a concussion to participants exercising after a few months. Considering the need for some clarity on this issue, a fifth parameter —*time post-injury*— was included to make up the "*FITTT"* principle in this thesis.

An important gap in knowledge translation identified in the literature is the influence of personal factors towards rehabilitative decisions. This implies that having all the knowledge about effective rehabilitation and its benefits may not always result in people adopting it. To explore some personal sociocognitive factors, the theory of planned behaviour (TPB) was used as a guiding framework in this thesis. The TPB is an influential and frequently cited model for predicting behaviour (Ajzen, 1991, 2011). It is theorised that key sociocognitive constructs such as *attitudes*, *perceived behavioural control*, and *subjective norms* are predictive of *intention*, that in turn predict behaviour (Armitage & Conner, 2001), such as exercise. Each of these constructs are thought to be formed by specific beliefs about a target behaviour. Figure 1.1 shows the theorised predictive pathways of the model. Using this model, this thesis will explore the predictive utility of the TPB constructs to understand factors that may influence the *intention* to participate in PPCS exercise rehabilitation. This theory is also chosen for the potential to not just describe sociocognitive constructs that predict *intention*, but also to target any constructs not predictive of intention and address these to improve engagement in the target behaviour.

Figure 1. 1

The Theory of Planned Behaviour



Note. From Ajzen (2019)

1.4 Significance of Research

Concussions cannot be prevented. The increasing popularity and fervour around contact sports such as soccer and mixed martial arts will only increase the odds of sports-related injuries. Children and older adults will always be susceptible to accidental falls, while people can get into motor vehicle accidents that result in non-sports related concussions. Most people recover from concussion, but the probability of injury across the lifespan suggests that a pool of people will continue to suffer from the consequences of PPCS and need help. While efforts can be put in place to educate people about the risk of concussion and safety measures to minimise an injury (such as helmets), the importance of effective rehabilitation after concussion cannot be overstated. The steps to recovery are just as important as preventive measures considering a condition that is so unpredictable and has shown to have persistent and adverse effects in some people.

A recent editorial on concussion raised the question on whether more can be done for concussed patients and if there are ways to deliver treatment more efficiently (Thomas et al., 2020a). While this issue was discussed as relevant in Australia, given the worldwide prevalence of concussion and PPCS, such questions are also applicable in a global context.

The need to effectively transfer knowledge from evidence-based rehabilitation to clinical settings may contain some answers towards better treatment for PPCS. If exercise ultimately proves to be effective in reducing PPCS irrespective of the injury cause, and the optimal program parameters are identified, this will pave the way for future efficacy studies. Depending on how it is delivered, and if this is done in a way that facilitates engagement in the program, exercise for PPCS may ultimately prove a more accessible treatment option than the current gold standard psychological approaches, which are largely unavailable in Australia. Therefore, this topic is significant and a worthwhile area for further research.

Recent estimates suggest that close to 170,000 cases of concussions are seen in hospitals annually in Australia (Thomas et al., 2020a). If 10-15% of these cases go on to develop PPCS, it is possible that 17,000 – 25,500 of individuals could be contributing to the national health and economic burden each year. While underreporting of injuries (Kroshus et al., 2015; Register-Mihalik et al., 2013) and inconsistency in diagnosing PPCS across healthcare settings (Polinder et al., 2018) make it difficult to work out the specific disease burden, the need for prolonged healthcare and reduced productivity could likely result in costs that runs into the millions. When considering the physical, financial, and emotional impact faced by caregivers and those who do not seek medical care, PPCS is a significant health problem that warrants research to improve treatment outcomes. Reducing the recovery time for PPCS can free up valuable healthcare resources for those with other needs.

1.5 Aim of Research

This thesis had three main aims; first, to identify the optimal exercise parameters for PPCS based on studies with only exercise as a mode of rehabilitation; second, to explore the current state of knowledge and attitudes about concussion and rehabilitation in the general community; and third, to investigate a set of sociocognitive constructs that could influence the likelihood of participation in a PPCS exercise rehabilitation program. The following hypotheses were investigated in three studies:

In study 1, a systematic review was undertaken to investigate two research questions

RQ1: *Is exercise for PPCS effective based on randomised controlled trials using unimodal exercise rehabilitation better than control conditions (i.e., prescribed rest, no action, stretching) to improve symptom outcome?*

RQ2*: If effective, what are the optimal exercise parameters (i.e., FITTT) that are beneficial for PPCS?*

In study 2, current knowledge and attitudes about concussion and rehabilitation in an Australian community sample was investigated. Potential differences in specific demographic variables of interest were investigated using the following hypotheses (**H3-H9**):

H3*: Participants who play contact sports would have higher levels of concussion knowledge than those who do not play contact sports.*

H4: *Participants who play contact sports would have safer attitudes towards concussion than those who do not play contact sports.*

H5: *Participants with prior concussion education would demonstrate higher levels of concussion knowledge than those without prior education.*

H6: *Participants with prior concussion education would demonstrate safer attitudes towards concussion than those without prior education.*

H7*: Participants with a prior history of concussion would demonstrate higher levels of knowledge than those without a previous injury.*

H8*: Participants with a prior history of concussion would demonstrate safer attitudes towards concussion than those without a previous injury.*

H9: *What are some of the common advice provided for recovery after a concussion?*

In study 3, the predictive utility of the sociocognitive constructs from the theory of planned behaviour, and the influence of past exercise habits were investigated using these hypotheses (**H10-H13**):

H10*: Positive attitudes would be associated with stronger intention to participate in exercise for PPCS.*

H11*: Higher perceived subjective norms would be associated with stronger intention to participate in exercise rehabilitation after a concussion.*

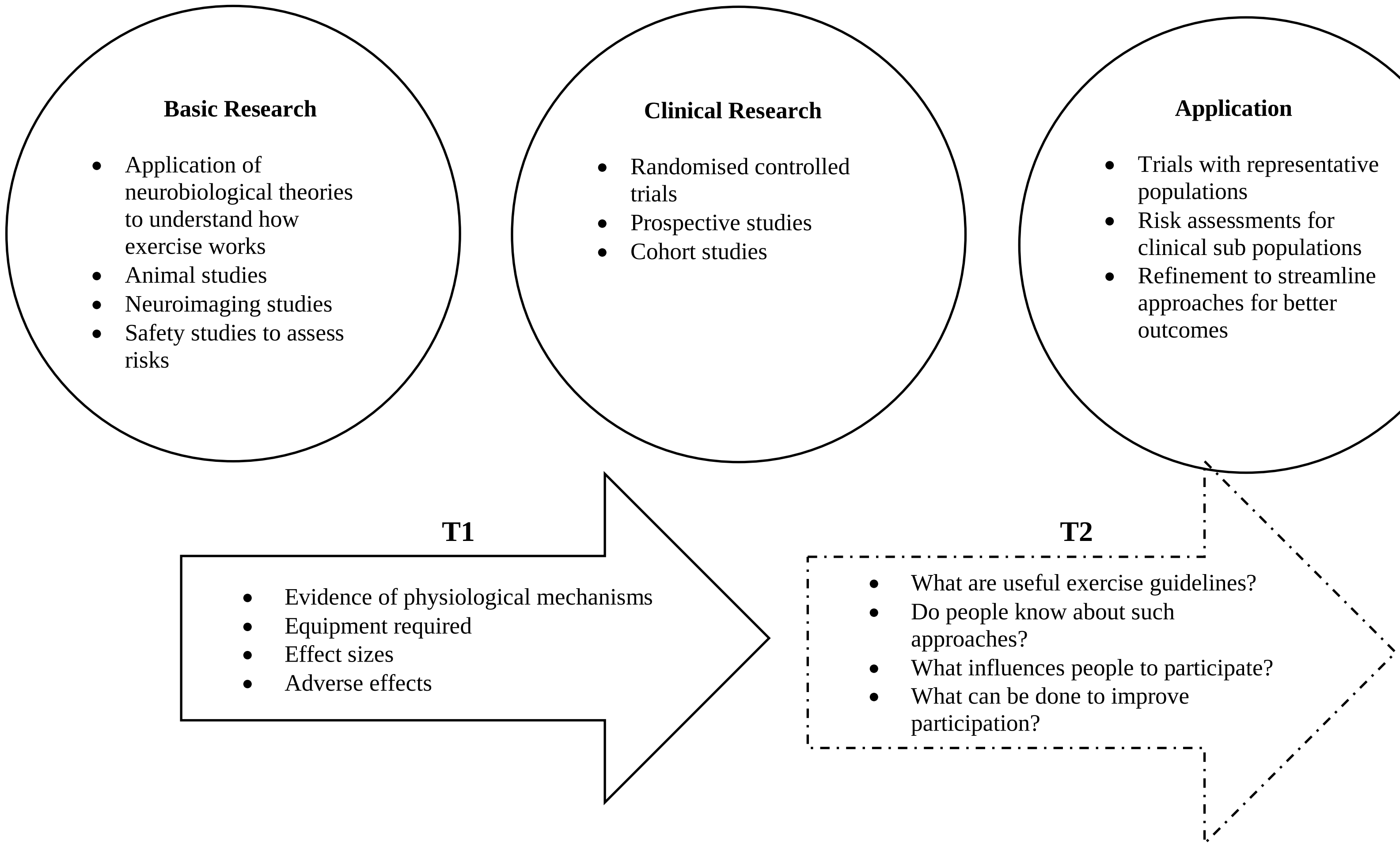
H12*: Higher perceived behavioural control would be associated with stronger intention to participate in exercise rehabilitation after a concussion.*

H13*: Past exercise behaviour would moderate the relationship between TPB constructs and intention to exercise.*

The research questions and hypotheses investigated in these three studies were expected to inform if the benefits of exercise made it a worthwhile consideration for wider populations. In the process, exercise parameters shown to be effective were identified to guide future exercise studies and adoption for different population groups. In line with recommendations from knowledge translation literature, if any knowledge gaps were identified, this information could be useful to shape future education programs. Sociocognitive constructs underlying intention to exercise could provide a better understanding on the factors behind such decisions and allow targeted efforts and addressing one or more of these factors. Figure 1.2 shows a brief illustration of how the research objectives of this thesis fit into a knowledge translation framework.

Figure 1. 2

A Model Integrating Research Questions to Address the Knowledge Translation Gaps Specific to PPCS Rehabilitation



Note. Adapted from Martin (2007). T1 = First phase of knowledge translation, T2= Second phase of knowledge translation

1.6 Scope of Research

There is much ambiguity around some terms that are commonly used in concussion and PPCS research. This makes it important to outline the scope of this research program so that the context of this thesis and the area of focus is clear.

First, this research focused on exercise rehabilitation that specifically referred to physical exercise. Other references to exercise such as mental exercise or cognitive exercise used in some multimodal programs are beyond the scope of this research. As defined for this research, only a prescribed and structured format of exercise was considered and this did not include incidental activity (e.g., walking the dog, household chores).

Second, while post-concussion symptoms have been defined as the onset of symptoms after a concussion, there are different lines of research exploring symptoms in different phases post-injury (e.g., few days after the injury, after 3 months). Inconsistent definitions of how long symptoms must be present before they are considered to be “persistent” adds to the complexity of characterising PPCS. For instance, the CISG states that PPCS is defined as post-concussion symptoms that persist after the typical recovery period of 10-14 days for adults (McCrory et al., 2017), but this is different for adolescents (e.g., symptoms are considered persistent after 28 days). As this research focused on exercise rehabilitation that drew largely from sports concussion literature with adolescent athletes, this thesis adopted the definition of “persistent” post-concussion symptoms (i.e., PPCS) as symptoms persisting after 28 days (Haider et al., 2020; McCrory et al., 2017). On this note, it is important to point out that this research focussed on helping people with PPCS recovery. More severe ramifications that can arise from repeated concussions, second-impact injury, more severe traumatic brain injuries or chronic traumatic encephalopathy (CTE) are beyond the scope of this thesis.

Third, while this research program acknowledges that current best practice for PPCS rehabilitation is an individualised, multimodal approach, the intent of this thesis was to explore the potential of exercise rehabilitation as a single modality. Thus, the complementary effects of one or other useful modalities (e.g., psychological therapy, psychoeducation) is not discussed in detail.

Lastly, a detailed elaboration of the biomechanics of concussions (Giza & Hovda, 2001, 2014) and the possible effects of exercise during recovery is presented elsewhere (Leddy, Haider, et al., 2018) and will not be the focus of this thesis. This research will only highlight some of the key physiological processes underlying exercise that are thought to contribute towards PPCS recovery.

1.7 Overview of Structure

This PhD was prepared for submission according to the PhD Thesis by Monograph Guidelines from Queensland University of Technology. The thesis comprised six chapters. Chapter 1 provided an introduction that outlined the definition of key concepts, the prevalence of the PPCS, problems with knowledge translation in PPCS rehabilitation research, and the significance of this research program. Chapter 2 presents a literature review that sets the context for the three studies that follow. Chapter 3 is a systematic review of studies on exercise for PPCS to determine the effectiveness of such rehabilitation and to identify exercise parameters that can be considered for further research and practice. Chapter 4 explores the knowledge and attitudes of an Australian community sample specific to concussion and PPCS rehabilitation. Chapter 5 examines the role of sociocognitive constructs as described by the theory of planned behaviour and how these constructs may influence the *intention* to participate in PPCS exercise rehabilitation. Finally, Chapter 6 will integrate the findings from the 3 studies and discuss the implications of the findings for research and clinical utility. The chapter will conclude with the overall strengths, limitations, and directions for future research.

1.8 Chapter Summary

This chapter outlined the research program for this thesis. PPCS can pose a considerable health challenge that requires addressing but there is a lack of clear evidence if exercise can be used as a therapeutic option. While exercise for PPCS seems promising based on studies focusing on rehabilitation for sports-related concussions, most studies have focused on a limited population comprising athletes or adolescents and evaluated multimodal rehabilitation programs. Such studies make it impossible to isolate the specific effects of exercise. The field has also not yet evolved to the point that the ideal exercise parameters for replication of research or adoption in current rehabilitative practice have been identified and this is a necessary step warranting attention. Further, it was brought to attention that the lag in adoption of exercise for PPCS or advice advocating for such exercise in the wider community could be attributed to knowledge translation gaps. Identifying knowledge gaps and factors that influence personal decisions towards participation in such exercise rehabilitation programs for PPCS could be important to inform future education programs and design exercise rehabilitation that better engages the community.

Chapter 2 – Literature Review

2.1 Chapter Introduction

Chapter 1 introduced the research problem by highlighting how some individuals experienced PPCS but there was a lack of a strongly supported evidence-based rehabilitation option to treat it. Exercise is promising and has gained traction, but studies evaluating its efficacy have primarily focused on collegiate athletes, and it is unclear if exercise rehabilitation can be applied to the general community with PPCS. To date, there are no studies that have explored exercise as rehabilitation for PPCS in the general community. Knowledge translation literature was used to identify possible reasons such as knowledge gaps and personal factors for evidence-based recommendations to be lagging for the community in the context of PPCS. It was suggested that identifying a set of specific and consistent parameters to guide future research and clinical recommendations could be an important first step. A better understanding of current knowledge and attitudes about concussion and rehabilitation along with personal decision-making factors regarding exercise rehabilitation could contribute towards designing exercise programs and making it more accessible to the community. Before exploring these factors, this chapter will first present a review of the literature on the definition of PPCS, aetiology of the condition, current rehabilitation approaches and how exercise might work to aid PPCS recovery.

2.2 Definition and Epidemiology of mTBI/Concussion

A traumatic brain injury (TBI) can be defined as 'physical damage to, or functional impairment of the cranial contents from acute mechanical energy exchange, exclusive of birth trauma' (Comper et al., 2005, p. 863). TBIs are one of the leading causes of death and disability and incur significant healthcare and economic costs globally (Dang et al., 2017; Hyder et al., 2007). TBIs are categorised as mild, moderate, or severe using measures of the levels of consciousness such as the Glasgow Coma Scale (GCS; Teasdale & Jennett, 1974) duration of post-traumatic amnesia (PTA), and assessment of structural damage using neuroimaging techniques (Binder, 1986; Maas et al., 2010). It is estimated that up to 85% of TBIs are mild traumatic brain injuries (mTBI)/concussion (Cassidy et al., 2004; Stulemeijer et al., 2008).

There are variations in how mTBI is defined in the literature (Carroll, Cassidy, Holm, et al., 2004). As part of recommending standardised criteria for research, the World Health Organisation Collaborating Task Force presented the following operational definition of mTBI: "MTBI is an acute brain injury resulting from mechanical energy to the head from external physical forces. Operational criteria for clinical identification include: (i) 1 or more of the following: confusion or disorientation, loss of consciousness for 30 minutes or less, post-traumatic amnesia for less than 24 hours, and/or other transient neurological abnormalities such as focal signs, seizure, and intracranial lesion not requiring surgery; (ii) Glasgow Coma Scale[1] score of 13–15 after 30 minutes post-injury or later upon presentation for healthcare. These manifestations of MTBI must not be due to drugs, alcohol, medications, caused by other injuries or treatment for other injuries (e.g., systemic injuries, facial injuries, or intubation), caused by other problems (e.g., psychological trauma, language barrier or coexisting medical conditions) or caused by penetrating craniocerebral injury" (Carroll, Cassidy, Holm, et al., 2004, p. 115).

mTBIs are commonly caused by motor-vehicle accidents and falls (Cassidy et al., 2004) with sports-related injuries estimated to make up 20% of injuries (Hon et al., 2019; Thomas et al., 2020b). mTBIs pose significant diagnostic challenges (Ponsford et al., 2000) (Ponsford et al., 2000) and the transient nature of mTBIs has resulted in injuries being unassessed or unreported (Iverson, 2005; Tellier et al., 2009). A review based on incidence rates of hospital-treated patients for mTBI noted that rates could double if considering those who fall through the cracks without professional consultation or a diagnosis (Cassidy et al., 2004). Specific to Australia, it is estimated that the number of people who do not recognise their injury could be ten times the number who receive medical care (Knox et al., 2017).

In Chapter 1, mTBI and concussion were both introduced as synonymous terms. However, an important distinction in terminology between the term “concussion” and “mTBI” has been raised in some studies. While both terms are often used interchangeably in the literature, it has been suggested that concussions are milder than mTBI across the spectrum of injury severity (Bigler, 2008). Positive findings through intracranial imaging has led to some researchers further distinguishing such injuries as *complicated mTBIs.* The findings are mixed on whether complicated mTBIs lead to more severe functional impairments (Karr et al., 2020).While subtle distinctions between some of these definitions are intended to further sub-classify mTBIs, the use of different terms to define the injury has shown to be not clinically meaningful in predicting onset or severity of PPCS (Theadom, Barker-Collo, et al., 2018). Table 2.1 summarises some of these common definitions used in the literature (Kamins & Giza, 2016) . In keeping with the focus of this thesis on injuries that are expected to be transient and mild enough to be considered for exercise rehabilitation, the term “concussion” will be used hereafter.

Table 2. 1

Common Definitions for mTBI and Concussion

Term	Definition
mTBI	Traumatic brain injury, GCS of 13–15 within 24 h of impact
Complicated mTBI	mTBI combined with intracranial imaging findings

Concussion	Clinical syndrome in which a biomechanical force, via acceleration-deceleration or rotational forces, transiently disturbs normal brain function. causing neurological, cognitive and/or behavioural signs and symptoms
Subconcussion	Proposed construct of biomechanical force causing subclinical injury in the absence of overt acute signs and symptoms

Note. From Kamins and Giza (2016)

2.3 Post-Concussion Symptoms

PCS are a constellation of physical (e.g., headache, dizziness, sleep problems, fatigue, tinnitus, diplopia, and photophobia), cognitive (e.g., poor memory, attention, and executive difficulties) and behavioural/emotional (e.g., depression, irritability, anxiety, post-traumatic stress and phonophobia) symptoms following a concussion (Alves et al., 1993; Dikmen et al., 2010; Kay et al., 1993). Headaches, fatigue, dizziness, and slowed thinking are the most common in the acute post-injury period while sleep disturbances, frustration and fatigue become more prominent as time progresses after the injury (Eisenberg et al., 2014). Most individuals recover within a few days/weeks after a concussion, but persistent PCS (PPCS) can manifest in some people beyond this typical recovery period (Bigler, 2008; Voormolen et al., 2018).

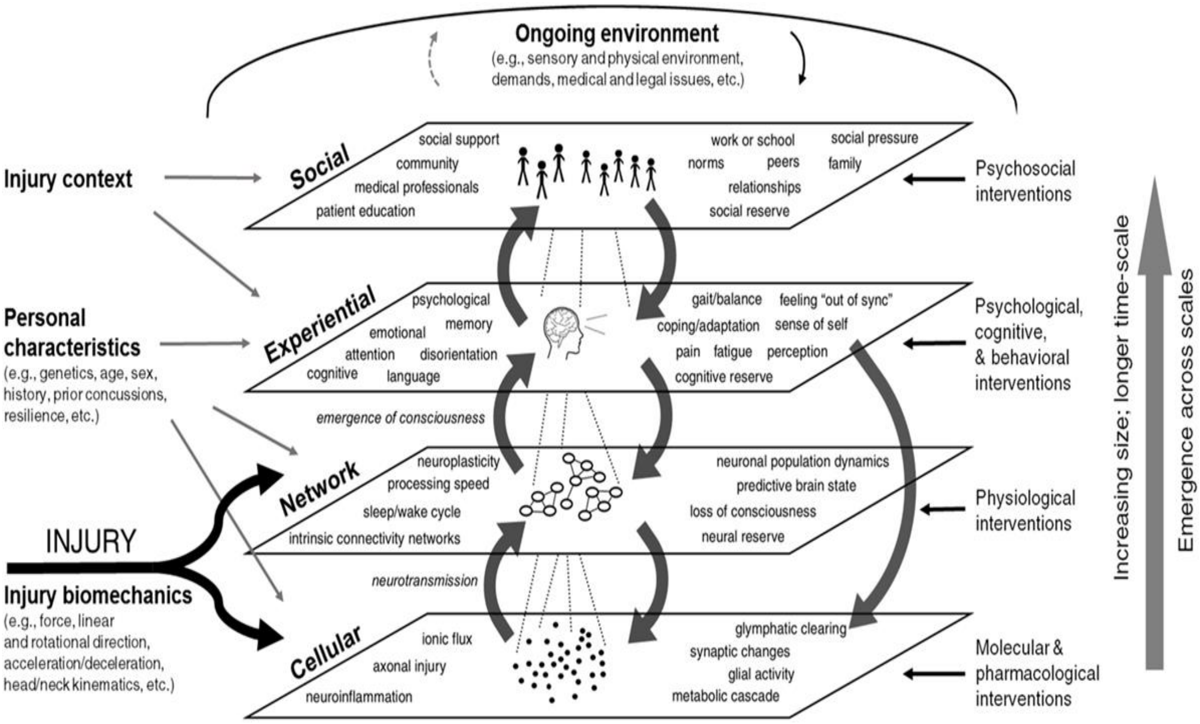
Individuals suffering from PPCS have been found to experience long-term functional impairment (Stulemeijer et al., 2008), reduced quality of life (Rees & Bellon, 2007), increased health service usage (Guérin et al., 2006), loss of productivity, and relationship problems (Mansfield et al., 2015). Taken together with the impact on the wider community such as caregivers and family members of patients, the burden of disease resulting from PPCS can be expensive and challenging to surmount.

The development of PPCS in some individuals after a concussion continues to be highly controversial because of the diverse, non-specific symptom profiles and unpredictability in symptom manifestation across individuals (Polinder et al., 2018). Figure 2.1 illustrates the different factors that can potentially lead to persistence of problems after a concussion across four domains: cellular, network, experiential and social (Kenzie et al., 2017). The first two domains are related to the biomechanics of the injury and how it can affect neurobiological functioning. The next two domains outline the influence of personal and injury related factors; the experiential domain depicts personal factors that can determine recovery trajectory while the social domain highlights the various environmental and psychosocial factors that can play a mediating role after the injury. The onset of PPCS in individuals can be a due to one or more affected domains that can be interrelated. Interventions that target the issues within each domain are shown on the right of the diagram. In summary, PPCS is complex, unpredictable, and varies greatly across individuals, necessitating treatment to be personalised and addressing multiple domains.

In explaining the onset of symptoms, Iverson (2019) argued that PPCS did not fulfil the criteria for a syndrome but offered a network perspective that suggested symptoms co-occur because of the interrelationship with one another (e.g., pain mutually reinforces anxiety symptoms), and not because of a common latent disease entity (e.g., post-concussion syndrome). Young (2020) summarised another common, longstanding proposition that while PPCS may be related to physical causes due to the injury in the acute stages, the maintenance and propagation of symptoms for protracted periods are solely attributable to psychological causes. The literature on PPCS remains divided as to whether symptoms occur because of physiogenic, psychogenic or a combination of these factors occurring at different phases (Boyd, 2014; Lishman, 1988). While these viewpoints may be useful to better understand the enigmatic PPCS, none of these theories have been able to effectively predict the onset of PPCS or the need for targeted treatment (Silverberg et al., 2015).

Figure 2. 1

Factors Influencing Concussion Recovery at Multiple Levels



Note. From Kenzie et al. (2017)

2.3.1 Diagnostic Criteria for PPCS

Apart from the complexities involved in factors leading to PPCS, there are inconsistencies in diagnostic criteria. First, some studies refer to PPCS as persistent post-concussion *syndrome*. As already mentioned, the use of the term "syndrome" is questionable because PCS has not been established as a unique and reliably identifiable constellation of lasting symptoms following mTBI (Arciniegas et al., 2005). More importantly, fixation on such terminologies adds little to establishing clear thresholds that can be useful to identify and help people with PPCS.

Second, there is no standard definition for how long symptoms must persist in order to qualify as PPCS. Some studies consider those who are "slow to recover" beyond the typical recovery phase (i.e., 10-14 days) as experiencing PPCS (McCrory et al., 2017). There are other studies, including the formal research criteria from the International Classification of Diseases 10th edition (World Health Organisation, 2016), that consider those with symptom presentation for longer than a month as diagnostic candidates for PPCS (Iverson et al., 2021; Leddy, Haider, et al., 2018). A more liberal classification, including the DSM-IV criteria, uses a 3-month threshold before people can be considered to be suffering from PPCS (Mercier et al., 2020; Permenter et al., 2021). Lagace-Legendre and colleagues (2021) sought to provide an expert consensus definition of PPCS and found support for a definition summarised as any symptom that cannot be attributed to a pre-existing condition, appeared within hours of a concussion, is present every day for three months after the injury, and significantly impacts at least one sphere of a person's life. The variation in such definitions applied across studies and in applied settings are evident; more importantly, this difference in criteria will also have an impact on how and when management advice is provided.

Further complicating such diagnostic issues are some studies attempting to distinguish the longer concussion recovery times associated with adolescents. These studies suggest that the term PPCS should be used when symptoms persist for more than 2 weeks in adults and more than 1 month (i.e., >28 days) in adolescents (Haider et al., 2020; McCrory et al., 2017).

The inconsistency in symptom presentation before PPCS can be diagnosed makes it complex to reliably diagnose the problem in people after a concussion. Table 2.2 shows the differences in criteria for PPCS between the DSM-IV, DSM-5, and the ICD-10. It should be noted that the DSM-5 no longer includes PPCS as a separate entity but as part of "mild neurocognitive disorder due to TBI". These variations in criteria can have far reaching implications in misdiagnosis and treatment recommendations. For example, studies comparing the diagnostic decisions based on these criteria have shown significant inconsistencies in PPCS diagnosis (Boake et al., 2005; McCauley et al., 2008; Voormolen et al., 2018).

Table 2. 2

Comparison of Diagnostic Criteria for PPCS in Widely Used Diagnostic Manuals

Symptoms	ICD-10	DSM-IV	DSM-5*
Headache	X	X	-
Dizziness	X	X	-
Fatigue	X	X	-
Noise intolerance	X	X	-
Irritability/lability/anxiety/depression	X	X	-
Sleep problems	X	X	-
Concentration problems	X[a]	X[b]	X[b]
Memory deficits	X[a]	X[b]	X[b]
Intolerance of alcohol	X	-	-
Preoccupation with symptoms	X	-	-
Personality change	-	X	-
Apathy	-	X	-
Perceptual-motor problems	-	-	X[b]
Social cognition problems	-	-	X[b]

Note. From Polinder et al. (2018)

* The DSM-5 classifies post-concussion symptoms under the category "Mild Neurocognitive Disorder due to Traumatic Brain Injury".

[a] subjectively reported

[b] objectively measured

A final point that deserves mention with regard to diagnosing PPCS is the possibility of malingering. The predominantly subjective symptoms in PPCS have led to some concerns about people making up or "faking" symptoms to gain financial compensation or when involved in post-injury litigation. This has led to calls from major professional bodies for validation measures to be included in PPCS assessments, as well as corroboration of the claimed injury consequences from multiple sources (e.g., healthcare professionals, symptom report, neuropsychological examination, neuroimaging) to improve diagnostic accuracy (Bush, 2013; Sweet et al., 2021).

2.3.2 Assessment of PCS

It has been established that PPCS is associated with a range of individual and injury related factors before, during and after an injury. For those who are slow to recover or are beset with symptoms for prolonged periods beyond the typical recovery period, it is ideal for the diagnosis and treatment plan to be determined by a multidisciplinary team (Arciniegas et al., 2005; McAllister & Arciniegas, 2002). Clinical assessment is centred around history of injuries, physical problems such as headaches, cervical and vestibular injuries that can co-occur with a head injury, other types of pain, and a self-report on the number and nature of symptoms (Barlow, 2014; Hadanny & Efrati, 2016). Neuropsychological testing can be used to assess cognitive problems (e.g., concentration, memory, attention) while psychological assessments help to determine current mental health difficulties (e.g., anxiety, depression). The non-specific and subjective symptoms make it necessary to gather information about social and legal factors including social support, other life stressors and if there is any involvement in litigation after the injury (Marshall et al., 2018). A thorough and extensive evaluation ensures that targeted treatment can be delivered to those who need it.

2.3.3 The Use of Neuroimaging

Evidence for reliable findings on neuroimaging are mixed for concussion (Polinder et al., 2018). While structural or functional abnormalities after concussions are not generally detectable with conventional imaging techniques such as computed tomography (CT) and magnetic resonance imaging (MRI) (Bazarian et al., 2007; Shenton et al., 2012; Zakharova, 2014), diffuse tensor imaging (DTI) is a more recent technique that has shown promise to characterise the subtle and heterogenous abnormalities in the brain (Eierud et al., 2014). This inconsistency in neuroimaging capability has been attributed to different mechanisms of injury and variations in imaging techniques or protocols. Some studies have reported intracranial abnormalities in up to 5% of patients with a GCS score of 15 and 30% or more in those with a GCS score of 13 (Borg et al., 2004; Bruns & Jagoda, 2009), suggesting that a classification of “mild” injury may still include further complications (i.e., *complicated mTBI*). Interestingly, a 12-month longitudinal study on the clinical utility of MRI-based imaging for mTBI found such objective measures to have no predictive value over and above demographic and clinical features (Hellstrøm et al., 2017). More studies are necessary to define specific imaging protocols that are sensitive and specific enough to identify neurological deficits before such methods can be useful for reliable clinical decisions (Asken et al., 2018).

2.4 Pathophysiology of Concussion and PPCS

Along with variations in the criteria for concussion, the precursor injury to PPCS, it is also evident that the injury can occur with minimal changes to commonly used diagnostic parameters such as the GCS, duration of loss of consciousness, and the period of post-traumatic amnesia. Such ambiguity has led to a vigorous search for a biomarker to establish more reliable diagnostic decisions. Neuroimaging, and other biomarker approaches, cannot yet provide a means of reliable, objective, and accurate diagnosis, nor predict symptom outcomes, including if PPCS will occur. Nevertheless, the lack of reliable biomarkers does not preclude a neurobiological change underpinning a concussion and/or symptom persistence.

A detailed elaboration of the physiological mechanisms after a concussion and potential PPCS may be beyond the scope of this thesis, but a brief account will provide some insights on reasons for persistent symptoms to manifest post-injury. Studies exploring the neurobiological changes after a concussion have suggested that the initial ionic flux and glutamate release in the acute stages after an injury result in significant energy demands from the brain. In efforts to restore homeostasis, cellular membranes shift into overdrive, resulting in potential disruptions to cerebral blood flow. This “metabolic crisis” is proposed as a possible explanation for post concussive vulnerability, making the brain less likely to recover from any consecutive injury in quick succession (i.e., second impact syndrome), and resulting in lasting deficits (i.e., PPCS) in some individuals (Giza & Hovda, 2001, 2014). Additionally, it is accepted that diffuse axonal injury (DAI) — the stretching or shearing of nerve fibres resulting from impact or acceleration/deceleration to various regions in the brain — results in disruptions to white matter connections, possibly causing prolonged cognitive impairment (Giza & Hovda, 2014; Jantzen et al., 2004). Both animal and human studies have found DAI to occur in more severe injuries (i.e., complicated mTBI) (Ryan & Warden, 2003) but more longitudinal studies are needed to establish a stronger cause-effect relationship between DAI and PPCS.

2.5 PPCS Rehabilitation

In the previous chapter, the thesis highlighted the importance of individualised, multimodal PPCS rehabilitation because of the heterogenous and unpredictable nature of the condition (Jaganathan & Sullivan, 2020; Mittenberg et al., 1996; Willer & Leddy, 2006; Wright & Sohlberg, 2021). Multimodal approaches may be effective but singling out a “best” combination is not yet possible. A beneficial clinical outcome for the patient is the raison d’etre of rehabilitation, but the variation in existing studies makes it difficult to replicate, understand and further refine ideal rehabilitation options. In this light, it appears logical to identify a single component such as exercise and explore specific parameters that yield the best outcomes. It is nevertheless important to discuss some of the existing rehabilitation approaches for PPCS as these approaches often complement exercise rehabilitation.

The most common rehabilitation approach for PPCS has been psychological treatment (Sullivan et al., 2020). Common psychological approaches include cognitive-behavioural therapy (CBT), counselling, providing education and reassurance and using relaxation techniques (Al Sayegh et al., 2010). These measures are expected to target the psychogenic issues thought to be the predominant reason for symptom to persist for prolonged periods in some lines of research, and provide reassurance that recovery is possible. The identification and reframing of maladaptive thoughts that are fundamental to these psychological approaches also help to address issues such as depression and anxiety after a concussion (Mittenberg et al., 2001; Mittenberg et al., 1996). As most individuals recover within the typical 2-week period, psychological approaches focus on increasing awareness of injury outcome, manage expectations and strategies to minimise reinjury (Mittenberg et al., 2001). Two systematic reviews on psychological approaches to treat PCS have concurred that cognitive behavioural therapy (CBT) may be promising (Al Sayegh et al., 2010; Sullivan et al., 2020). Interestingly, both these reviews point out the need to interpret the findings with caution due to limited support for the efficacy of these approaches and the need for more comparative trials.

For those experiencing physical symptoms such as neck or back injuries, physical therapy is used (Lundblad, 2017). Some post-concussion symptoms can include more debilitating vertigo or balance problems and specific physiotherapy or vestibular therapy is recommended (Adams & Moore, 2017; Gottshall, 2011; Sheese & Hammeke, 2014). A study by Ellis and colleagues (2015) is worthy of mention here. The authors categorised post-concussive injuries according to symptom prominence; namely into vestibulo-ocular, cervical spine, or autonomic dysfunction. The study recommended that those with vestibulo-ocular and orthopaedic (cervical spine) problems should be referred to the respective specialists and more active rehabilitation such as exercise to be only suitable for those with autonomic dysfunction. This study was based on athletes and more replication is necessary to determine if such a classification is practical and useful for the wider population.

Medication has also been used to manage other physical symptoms such as headaches, nausea, dizziness, and sleep problems (Meehan, 2011). As with other rehabilitative approaches, there is no clear indication that one or more of these medications work to alleviate PPCS per se and most studies have called for larger controlled trials to better evaluate the efficacy of such pharmacological approaches (Wright & Sohlberg, 2021).

2.6 Exercise Rehabilitation for PPCS

A central focus of this thesis is to explore exercise rehabilitation for PPCS and consider how it can be made accessible to the general community. It has been established that an interdisciplinary approach that is individualised may be the best approach, even though the benefits of single modality programs are still being explored. Studies that focus on unimodal approaches are clearly important to determine what exactly works and how single modality treatment can complement multimodal approaches efficiently. Compared to other single modality approaches, the exercise for PPCS literature has been more recently established, and the first reviews of it have recently appeared (Baker et al., 2020; Howell et al., 2019; Worts et al., 2019). This literature is now closely explored to determine what is known about how it has been delivered, whether it works, and the mechanisms that underpin benefits for PPCS.

2.6.1 Animal Studies of the Effects of Exercise after Concussion

The gateway to exercise as a safe, rehabilitation option for PPCS was initiated through animal studies. In the pursuit of better understanding the pathophysiology behind concussion and post-concussion exercise, early studies on rodents used fluid-percussion to simulate concussion. These studies found that exercise was detrimental to neurotrophic expression and cognitive performance (Griesbach, Gomez-Pinilla, et al., 2004; Griesbach, Hovda, et al., 2004). Such studies were instrumental in shaping the initial approach to the clinical management of concussion in humans, which recommended prolonged rest after a concussion.

Subsequent animal studies of exercise post-concussion identified that the context for exercise (e.g., forced versus voluntary) led to different outcomes. Griesbach, Tio, et al.

(2012) established that voluntary, but not forced treadmill exercising, led to increased levels of brain-derived neurotrophic factors (BDNF) in rodents although favourable effects were only observed after a period of delay post-concussion. Further work in this area led to the understanding of the importance of the timing of voluntary exercise after a concussion. For example, it was shown that undertaking activity too soon post injury did not lead to similar BDNF upregulation and resulted in poorer cognitive performance as compared to a condition that participated in exercise after a period of delay; these findings suggested that exercise when administered too soon could disrupt the molecular responses, compromise plasticity, and delay recovery (Griesbach, Gomez-Pinilla, et al., 2004; Griesbach, Vincelli, et al., 2012).

In contrast, a more recent study by Mychasiuk et al. (2016) demonstrated early voluntary exercise (i.e., 1-3 days post-concussion) to not be detrimental after a concussion in rodents with improvements observed in both cognitive and motor functioning. While this study contradicted earlier findings on the detriments of commencing exercise too soon after a concussion, it is difficult to draw conclusions about exercising in the acute stages based on just animal studies and without further replication. Investigating the possibility of exercise post-concussion using animal studies has served as a cornerstone to understand and consider exercise as a possible rehabilitation option. However, animal models cannot entirely replicate the effects of a concussion in humans (Shultz et al., 2017). It is also not possible to assess some of the defining subjective complaints for this condition in humans, such as PTA and other emotional problems (e.g., depression, anxiety). Some of the conditions imposed in animal studies (e.g., voluntary versus forced, social deprivation, avoidance learning) cannot be ethically translated to human studies (Wogensen et al., 2015). Finally, the contusive injuries simulated in animal experiments do not correspond directly to human head injuries experienced through sports or accidents (McCrea et al., 2009). The unique shape of the human skull that results in a particular anatomical distribution of brain injury makes it near impossible to replicate a concussion with the associated peri-injury factors in animal models (Bazarian et al., 2006).

2.6.2 Human Studies of the Effects of Exercise after Concussion

Building on findings from animal studies, the "cocooning" model of care that emphasised rest or post-injury sensory deprivation (Lee & Fine, 2010), started to be questioned. It was suggested that long periods of inactivity post-injury could result in people adopting a sick role, making it less likely for them to recover (Leddy, Haider, Ellis, et al., 2019; Sullivan et al., 2018). In a randomised controlled trial (RCT), Thomas et al. (2015) found strict rest to offer no additional benefit over usual care in an adolescent population with PPCS. Buckley et al. (2016) found that compared to usual care, a prescription of one day of strict physical and cognitive rest (e.g., withheld from all activities including studying/schoolwork, computer/mobile phone use) did not speed up PPCS recovery. Similarly, Ledoux et al. (2021) reported no significant difference in symptomology 2 weeks post-injury between youths who initiated exercise 72 hours after an injury as compared to those who rested till symptomatic. Other studies add that inactivity could worsen fatigue, cause frustration, and lead to depression in people with PPCS (Berlin et al., 2006; Grabowski et al., 2017) as well as physical deconditioning for athletes (Leddy et al., 2007). A systematic review found that even when rest was recommended, much ambiguity surrounded terms such as "cognitive rest" and there was considerable variation in interpretations of what entailed rest (McLeod et al., 2017). While rest in the acute period after an injury is important to minimise risks of reinjury and to monitor symptoms, more recent consensus from sports concussion management guidelines is that rest beyond two days (i.e., 48 hours) can be counterproductive (DeMatteo et al., 2020; Silverberg & Iverson, 2013).

Leddy and colleagues (2010) were one of the first research groups to establish the safety of exercise rehabilitation for people with PPCS in the acute post-injury stage (e.g., first week after injury). Further studies by Leddy and colleagues were instrumental to introducing the idea of progressive exercising just below an intensity that could trigger symptoms (i.e., termed *graded sub-symptom threshold exercise*) in the acute stages (Leddy et al., 2013; Leddy, Master, et al. 2021; Leddy, Haider, Ellis, et al., 2019; Leddy, Haider, Hinds, et al., 2019; Leddy, Hinds, et al., 2018; Leddy et al., 2010).

Gagnon and colleagues used an active rehabilitation program that included exercise as the core treatment with coordination and mental visualisation techniques and found significant improvements in PPCS symptoms (Gagnon et al., 2009; Gagnon et al., 2016). Grool et al. (2016) found that participation in activity within 7 days of a concussion to be associated with a lower risk of PPCS in a children and adolescent population, but the exercises were self-reported and not prescribed in this study. Kurowski et al. (2017) compared a home-based subsymptom exercise program to a stretching program and found the exercise program to be more effective in PPCS recovery. More recently, Chrisman et al. (2019) explored the effectiveness of exercise by allowing participants to choose a preferred mode of exercise. The study found participants involved in the exercise program to experience rapid improvements in their PPCS as compared to the control group and the improvements were maintained after 6 months. These studies corroborate that exercise can offer benefits to PPCS rehabilitation. However, the inconsistent methodology (e.g., different population profiles, lack of control group) and lack of clear parameters (e.g., different exercise intensity, duration) bring to light some of the challenges in moving the evidence to wider rehabilitation settings.

2.6.3 Physiological Mechanisms of Exercise

This section will provide a brief overview on the physiological mechanisms of exercise that are thought to be at play to reduce PPCS symptoms. The effects of exercise have been extensively studied on multiple aspects of brain function in humans (Barnes et al., 2003; Hillman et al., 2008; Mandolesi et al., 2018). Research has established that exercise increases parasympathetic activity and cerebral blood flow. Among other things, the salutary effects of exercise are believed to occur through one or more of the following processes:(1) cardiovascular activity that increases oxygen saturation, cerebral blood flow (CBF) and angiogenesis; (2) alterations in neurotransmitters in the brain; (3) increases in neurotrophic factors such as BDNF, insulin-like growth factors and nerve growth factors and (4) neuroplasticity (Bray et al., 2021; Lojovich, 2010).

As already established, the debilitating symptoms of PPCS are thought to originate from metabolic and physiological changes that result in altered functioning of the autonomic nervous system (i.e., blood-brain barrier disruption, reduced cerebral blood flow) and systemic physiology regulatory dysfunction (i.e., heart rate fluctuations, circadian rhythm disruption) (Leddy et al., 2007; Leddy, Haider, et al., 2018). In an fMRI study, Leddy et al. (2013) found aerobic exercise restored patterns of hemodynamic response to baseline levels during a cognitive task to a greater degree than a placebo stretching condition. The study found evidence of activation in brain regions during cognitive tasks that were otherwise not observed in healthy controls, lending support for abnormal CBF regulation to be a feature of PPCS. In a study on exercise intolerance due to PPCS, Clausen and colleagues (2016) demonstrated that some people could have problems maintaining exercising intensity due to abnormal CBF regulation resulting from altered sensitivity to carbon dioxide in the circulatory system. The authors posited that the return of CBF regulation and tolerance to exercise could be potential physiological markers of recovery from PPCS. In a pre-post study, Yuan et al. (2017) used DTI to quantify neurological changes in adolescents with

PPCS following aerobic activity and found significant increases in structural connectivity as compared to before the intervention for the PPCS patients. Overall, the findings suggest that aerobic exercise is expected to exert a protective physiological effect on multiple organ systems — cardiovascular, pulmonary, central nervous system, autonomic nervous system, and neuroendocrine systems — and this could be how it restores the dysfunction resulting from PPCS (Chieffi et al., 2017; Lawrence et al., 2018).

2.6.4 Psychological Mechanisms of Exercise

Exercise has also demonstrated a positive impact on more subjective psychological PPCS symptoms such as depression (Krogh et al., 2011), anxiety (Broshek et al., 2015; Wipfli et al., 2008), fatigue (Larun et al., 2019), and cognitive problems. The benefits of exercise can be extended to positive mood changes, increased self-esteem, and improved sleep (Scully et al., 1998; Sharma et al., 2006). Given that PPCS can lead to negative affect, lowered self-efficacy and sleep disturbance, exercise could benefit those affected by such symptoms. Wankel and Berger (1990) add that exercising in groups can offer social benefits of meeting people with similar interests and motivating one another. An exercise environment with people experiencing similar symptoms is also potentially beneficial to normalise some of the issues and help people share coping strategies. However, the benefits of such exercise in a rehabilitative context can only be harnessed if people know about its effectiveness. Studies support that education and knowledge influence the uptake of effective rehabilitation (Peters & Keeley, 2017). With much of the exercise rehabilitation literature focusing on adolescent athletes, it is important to consider public knowledge on concussion, potential consequences of post-concussion symptoms and effective rehabilitation.

2.7 Public Knowledge on Concussion and Rehabilitation

Concussions and post-concussion symptoms can cause persistent functional problems in some individuals. Along with improving self-awareness on the possible consequences and rehabilitation options when affected by symptoms, knowledge around concussion can also be useful for caregiving and attending to others. The popularity of contact sports and the possibility of concussion in day-to-day accidents makes this a pertinent issue that extends beyond just sports and an essential area for this thesis to investigate. As suggested by knowledge translation literature (Bowen et al., 2009, El-Kotob et al., 2018), identifying knowledge gaps in these areas can be key to improving awareness and possibly seeking out effective rehabilitation.

Studies on concussion knowledge in the community are few and far between. Most studies on concussion knowledge and attitudes have focused on sports communities, coaches, and parents of athletes (Waltzman & Daugherty, 2018). In some of these studies extended to family members of athletes, Waltzman and Daugherty (2018) found that while the American public demonstrated a high level of concussion knowledge, more targeted efforts were required to help them identify symptoms after an injury. In a study on community club rugby stakeholders, van Vuuren et al. (2020) observed knowledge on concussion to be lacking despite the participants' close involvement with rugby at a professional club level. Kerr et al. (2021) investigated concussion knowledge and care-seeking attitudes among parents of middle school children in the United States and found both knowledge and care-seeking attitudes to be high. However, knowledge deficiencies were reported in identifying more subjective, emotional symptoms as well as uncertainty about access to post-concussion treatment. A systematic review on coach and parent knowledge summarised these trends by highlighting similar gaps in concussion knowledge and recommended more targeted education efforts in these populations (Feiss et al., 2020). While such findings from coaches and parents can be considered to make up the wider community, this limited scope of research does not provide information about concussion knowledge among people who are non-athletes or do not have any associations with sports. The extent of research and expert opinion that has made its way to the Australian population is also currently unclear and needs further investigation for future education programs to be developed accordingly.

2.7.1 Measures of Concussion Knowledge and Attitudes

Another important area to consider with regards to exploring concussion knowledge and attitudes is how this is currently measured and if it is sufficiently comprehensive to provide insights into the extent of knowledge in the community. Poor assessment measures may not adequately capture the necessary areas of knowledge and attitude gaps. Different measures of concussion knowledge have been used over the years. One of the earliest studies by Gouvier et al. (1988) used a questionnaire of 25 statements about head injury, recovery from concussion, and sources of concussion knowledge. Subsequent questionnaires were developed to assess knowledge about specific mechanisms of injury definition, short and long-term sequelae, and return-to-play (RTP) decisions in sports (Livingston & Ingersoll, 2004; Sye et al., 2007), but the psychometric properties of these questionnaires were unavailable (Rosenbaum & Arnett, 2010). The College Football Head Injury Survey (Sefton, 2003) and Knowledge and Attitudes about Sports Concussion Questionnaire (KASCQ-24; Simonds, 2004) were more recent revisions to assess concussion knowledge and attitudes but lacked validity for further replication (Chapman et al., 2018). For example, the College Football Head Injury Survey focused exclusively on knowledge with only a few items assessing attitudes while the revised version of the KASCQ-24 assessed knowledge and attitudes specific to RTP guidelines.

The Rosenbaum Concussion Knowledge and Attitudes Survey (RoCKAS; Rosenbaum & Arnett, 2010) was developed to address some of the gaps in existing measures but is not without limitations. A study investigating the RoCKAS found that the knowledge section was a valid and reliable measure but not the section assessing attitudes (Chapman et al., 2018). Nevertheless, the RoCKAS is the most current and widely used measure to assess knowledge and attitudes about concussion. While measures on concussion knowledge and attitude have been improved over the years, it is noteworthy that almost all the questionnaires do not assess rehabilitation knowledge. A focus on rehabilitation may seem trivial when most people recover after a concussion, but with the increasing popularity of contact sports and wide possibilities of non-sports related concussions, identifying if people know what to do if they experience PPCS after a concussion can help to address any gaps in this important area.

2.8 Individual Factors Affecting Decisions to Exercise

Knowledge and attitudes are important factors that can determine whether an individual is willing to participate in rehabilitation after a concussion, but there can also be other sociocognitive factors that affect intentions. A final component of this thesis is to investigate sociocognitive factors that have shown to influence the intention to participate in exercise for PPCS. Exercise literature suggests that, as with other health behaviours, psychosocial models can explain the uptake and continuation of exercise (Bozionelos & Bennett, 1999; Maddux, 1993). Exercise studies have also emphasised a need to understand factors such as motivation and barriers to exercise in order to develop programs that maximise the likelihood of participation (Ebben & Brudzynski, 2008). If exercise shows promise as a PPCS rehabilitation option for wider adoption in this thesis, a better understanding of these factors can provide insights on future education and exercise program design.

The theory of planned behaviour (TPB) is an influential and frequently cited model for behaviour prediction (Ajzen, 1991, 2011). The theory has been applied in more than 2,000 empirical studies (Ajzen, 2020), and has contributed towards understanding sociocognitive factors that influence a range of health-related behaviours such as smoking, eating behaviours, treatment seeking and exercising (Godin & Kok, 1996). The theory posits that behaviour can be predicted by *intention* that is further determined by three constructs:

perceived behavioural control, *attitudes,* and *subjective norms* (Armitage & Conner, 2001). The correlation between these constructs have been shown to be reasonably moderate in a range of studies with *intention* explaining up to 66% of the variance in behaviour prediction (Ajzen, 2020; Godin & Kok, 1996). Specific to participation in physical activity, Hagger et al. (2002) concluded from a meta-analysis that attitudes, and to a lesser extent *perceived behavioural control*, were the most influential predictors of behaviour. More importantly, apart from identifying these constructs, these constructs are modifiable to improve *intention* towards a target behaviour. As such, exploring how these constructs influence *intention* to participate in PPCS exercise rehabilitation may hold the key to unlock specific areas that require more attention.

Studies on factors that could lead to better uptake of exercise suggest that common factors include having more time, less work commitments and better motivation (Ebben & Brudzynski, 2008). Closely corresponding to some of these factors are common barriers such as lacking time to exercise, busy work commitments and not finding sufficient reasons to exercise (Grubbs & Carter, 2002). While some of the solutions for these factors may be beyond the development of exercise programs for PPCS rehabilitation, it is nevertheless important aspects to be investigated as part of this overall research. The information on ideal features and possible barriers can be considered when designing exercise rehabilitation, keeping in mind possible factors that may facilitate uptake in such programs.

2.9 Gaps in the Literature

The evidence from the literature supports the physiological and psychological benefits that exercise has to offer for PPCS patients, but there is a lack of consistent parameters that can be considered for wider clinical or research utility. Knowledge translation literature highlights the importance of knowledge about a condition and potential avenues for rehabilitation but the extent of knowledge about concussion or rehabilitation options in the general, or more specifically, Australian community is unclear. Thus far, no research has investigated knowledge about PPCS rehabilitation, or personal factors influencing decisions to exercise for PPCS, suggesting that these are areas that warrant further exploration.

2.10 Chapter Summary

This chapter reviewed the literature pertaining to definitions of PPCS, the assessment of the condition, existing rehabilitation options, and potential physiological and psychological mechanisms underlying the benefits of exercise rehabilitation for PPCS. Some of the identified gaps in the literature included the need to further establish the effectiveness of exercise for wider populations apart from adolescents and athletes, highlight the important preliminary steps to identify consistent exercise parameters for potential adaptation for the community, and examine current knowledge about concussion and its management in the community. The next three chapters will focus on investigating these gaps using three studies.

Chapter 3: Systematic Review of Exercise Parameters for Persistent Post-Concussion Symptom Rehabilitation

3.1 Chapter Introduction

This chapter will focus on Study 1; the aim of which was to explore whether exercise rehabilitation for PPCS is effective; and if so, the exercise parameters that contribute positively to PPCS recovery. Knowledge translation and intervention design studies have pointed out that identifying and defining such parameters is the first step towards effectively implementing rehabilitation at a community level (Chandler et al., 2016; Colquhoun et al., 2017). By systematically reviewing the relevant literature, it is possible to determine if there is enough evidence to support the use of exercise for PPCS, and if so, for whom such recommendations can be made, along with how key components of such programs can be adapted (e.g., timing, duration, intensity, etc). This would help to answer the question of whether this approach is ready for translation for the community; for example, if there is support for it from trials outside sport-related concussions (SRC) or using members of the general population, as opposed to athletes.

Further as the systematic reviews of psychological approaches for PPCS have shown, when the promising results from individual trials are evaluated using rigorous review methodology, gaps in the body of evidence can emerge. For example, by focusing only on high quality evidence, or by applying strict standards for the defining injury, it may be possible to identify that the evidence is weaker than first thought. This is not a new nor trivial consideration for mTBI research (Cancelliere et al., 2014; Cassidy et al., 2014); similar points have been made by the WHO collaborating task force on mTBI. Earlier reviews of psychological interventions for PPCS have observed that the interventions often lack detailed description, and this is a major limitation to determine the strength of such interventions, their replicability of results, and the translation potential that can be drawn from such approaches.

In the case of exercise for PPCS, several programs are being trialled; but these programs have not yet been systematically appraised in a review methodology that seeks to draw out only studies with exercise modalities and identify the program parameters in detail. Further, given that exercise intervention can be appraised according to principles such as FITTT, this evaluation is needed. If this review can pinpoint the exercise parameters that show benefits for PPCS, this could aid in the eventual translation to the community. It would also assist future research by unifying these efforts around the most promising exercise protocols, and in particular, through the identification of the *principles* that underpin the approaches with the most evidence.

The following section of this chapter includes text that has been prepared for submission as a publication to the Journal of Sport Rehabilitation. Therefore, this section includes a brief background to PPCS, before proceeding to the detail of Study 1.

Post-concussion symptoms (PCS) are a constellation of physical, cognitive, behavioural, and emotional symptoms that can manifest after a concussion. Symptoms can persist in up to 10-15% of concussed individuals (Polinder et al., 2018; Willer & Leddy, 2006) and symptom persistence beyond the typical recovery period of 10-14 days for adults and beyond 28 days for adolescents suggests a need for further evaluation and treatment (Permenter et al., 2021; Quinn et al., 2018). Individuals with persistent PCS (PPCS) experience considerable burden through lower life satisfaction (Stålnacke, 2007), reduced productivity (Chu et al., 2017; Nolin & Heroux, 2006) and increased health care costs (Thomas et al., 2020a). PPCS have been reported in some individuals up to 1-year post-injury, highlighting the protracted impact of the problem (Ewing-Cobbs et al., 2018; McMahon et al., 2014).

Effective rehabilitation for PPCS is necessary but there is no evidence-based approach with specific recommendations to date (Leddy, Hinds, et al., 2018; Moser & Schatz, 2012).

While current rehabilitation is centred around rest and psychological approaches, these measures have yielded mixed and limited effectiveness in resolving PPCS (Al Sayegh et al., 2010; Sullivan et al., 2020). Over the past decade, controlled aerobic exercise has gained traction as a promising rehabilitation approach for PPCS (Leddy et al., 2016). The convenience of exercising anywhere, with remote supervision, and at an individually calibrated intensity, makes this an appealing option. However, well-designed studies highlighting specific exercise guidelines that confer the best benefits are sparse. A systematic review of the current literature on exercise interventions for PPCS can provide timely and valuable insights on optimal exercise parameters that can be better utilised for clinical and applied settings.

Understanding the pathophysiology of concussion can shed some light on why exercise could have beneficial outcomes for PPCS. The onset of PPCS has been attributed to reduced cerebral blood-flow (CBF), blood-brain barrier disruptions, and neurochemical alterations in the brain due to fluctuating energy demands after a concussion (Giza & Hovda, 2001, 2014). The impact from a concussion can cause disruptions to brain stem regions responsible for autonomic nervous system regulation. The resulting dysregulation of the autonomic nervous system is thought to affect cardiovascular and respiratory processes that in turn leads to physiological symptoms in individuals during physical exertion in the acute stages post-concussion. Rest is thus advised in the acute post-injury period to minimise metabolic energy consumption and divert the necessary resources for cerebral recovery (Leddy et al., 2007; Leddy, Haider, et al., 2018). The well-established, salutary effects of exercise such as increased CBF, alterations in neurotransmission, neuroplasticity, oxygen saturation and release of brain-derived neurotrophic factors (BDNF) are thought to play a restorative role in people experiencing PPCS by re-establishing homeostasis (Leddy et al., 2016). Non-physiological outcomes of exercise such as reintegration into social and recreational activities, normalising of conditions, and regaining of confidence can also possibly contribute towards positive outcomes for PPCS patients (DiFazio et al., 2016; Ritter et al., 2019).

The evidence for exercise rehabilitation to aid PPCS recovery has made considerable progress over the years. Initial exertion tests to determine exercise tolerance at the early stages after a concussion lent support to baseline tests such as the Buffalo Concussion Treadmill Test (BCTT; Leddy et al., 2013; Leddy et al., 2010). The BCTT, or an equivalent graded baseline exercise exertion test, is now used in most, if not all, exercise studies to determine the intensity at which a patient can exercise before symptom exacerbation (i.e., symptom threshold), design exercise protocols, make diagnostic and treatment decisions, and assess readiness to return to normal activities (Leddy et al., 2016; Leddy et al., 2011; Leddy et al., 2013).

While the idea of a safe, subsymptom threshold exercise for PPCS laid the foundation for most exercise studies that followed, considerable differences in experimental design and restricted samples in studies have led to difficulties in translating findings from the literature to applied settings. For example, important exercise parameters such as duration, intensity and modality are considerably varied across studies. This is understandable as some of the studies were carried out to achieve different purposes (e.g., efficacy of protocols, safety of exercise) under controlled conditions. Additionally, most of the early studies have been carried out on younger adults or athletic populations with sports-related concussions, making it challenging to generalise findings to wider populations. This is best summarised by a recent review of exercise studies on PPCS, in which only 1 out of 25 studies included participants with a diverse age range of 18-65 years, while all the other studies comprised participants under the age of 20 (Haider et al., 2020).

Several studies on exercise for PPCS have explored the use of exercise by administering it as part of multimodal interventions (Bailey et al., 2019; Chan et al., 2018; Dobney et al., 2018; Gagnon et al., 2009; Gagnon et al., 2016; Gauvin-Lepage et al., 2020; Grabowski et al., 2017). Exercise was added as an auxiliary component to traditional psychological approaches, but this addition made the evaluation of exercise more challenging to isolate. Other studies measured exercise using self-report measures, which led to difficulties operationalising parameters for replication (Grool et al., 2016; Lawrence et al., 2018; O'Brien et al., 2017). For example, considerable variations in the reported intensity, duration, and modality along with the difficulty verifying self-reported responses could lead to misleading conclusions about exercise parameters. Considerable experimental biases in some of these studies such as a lack of participant randomisation or blinding of experimenter to conditions could also result in misinterpretation of the efficacy of exercise interventions. While most of the multimodal studies undertaken are aligned to PPCS management guidelines to treat symptoms across domains, the issue of not being able to delineate the specific effects of exercise without controlled and standalone protocols remained.

In the last five years, thirteen reviews on exercise interventions for PPCS have been published. Eight of these were systematic reviews (Baker et al., 2020; Coman et al., 2022; Howell et al., 2019; Lal et al., 2018; Langevin et al., 2020; McIntyre et al., 2020; Reid et al., 2022; Rytter et al., 2021), three were critical appraisals (Kulpa et al., 2020; Prince et al., 2020; Ritter et al., 2019)., and two were narrative reviews (Haider et al., 2020; Worts et al., 2019). These reviews have generally found exercise to be effective and have made some useful contributions to the literature. For example, Howell et al. (2019) proposed that future exercise interventions should be modelled after American College of Sports Medicine (ACSM) guidelines. Worts et al. (2019) recommended that exercise can be calibrated for a wider group of individuals based on pre-existing fitness levels. Baker et al. (2020) concluded that various modes of exercise at different intensities were effective and safe for the post-acute phase of concussions. Notably, all thirteen reviews included studies with multimodal approaches, self-reported exercise, and respective cohort studies with none offering a comprehensive set of evidence-based exercise parameters for this context.

The need to identify specific exercise parameters that are optimal for PPCS rehabilitation has been reiterated in several studies (Howell et al., 2019; Kurowski et al., 2017; Leddy et al., 2016; Prince et al., 2020). Identifying and utilising these recommended exercise parameters in PPCS rehabilitation can have implications for individuals experiencing PPCS such as cost savings, less time spent in rehabilitation and faster return to normal functioning after a concussion. If a 4-week exercise program is found to be just as effective as an 8-week program, it could help to develop future programs that are shorter and more optimal for clinical recovery. Identifying optimal intensities and frequency of exercise that may be beneficial can result in more targeted calibration of exercise for non-athletic populations.

To address the need for evidence-based advice around the specific exercise parameters recommended for PPCS, and extend on the prior reviews, this study focused only on randomised controlled trials (RCTs). This is the first systematic review of controlled studies using exercise as a standalone intervention to provide an unconfounded set of exercise parameters for PPCS rehabilitation. For this purpose, exercise will be defined as "a subset of physical activity that is planned, structured, and repetitive, and has a final or an intermediate objective to improve or maintain a predetermined outcome" (Caspersen et al., 1985, p. 126). The "*FITT*" principle was proposed by Winters-Stone et al. (2014) to denote the specific parameters across which exercise can vary; namely, its frequency, intensity, time (i.e., program duration), and type of exercise. Lawrence et al. (2018) proposed an additional parameter of "time post-injury" considering the ambiguity around this important aspect in

PPCS exercise literature. To advance the PPCS literature, an integrated "*FITTT*" principle was adopted for data extraction and reporting in this review.

The research questions that this review sought to address were as follows:

RQ1: *Is exercise for PPCS effective based on randomised controlled trials using unimodal exercise rehabilitation better than control conditions (i.e., prescribed rest, no action, stretching) to improve symptom outcome?*

RQ2*: If effective, what are the exercise parameters (i.e., FITTT) that are beneficial for adoption and replication in future PPCS rehabilitation studies?*

3.2 Method

3.2.1 Databases and Search Terms

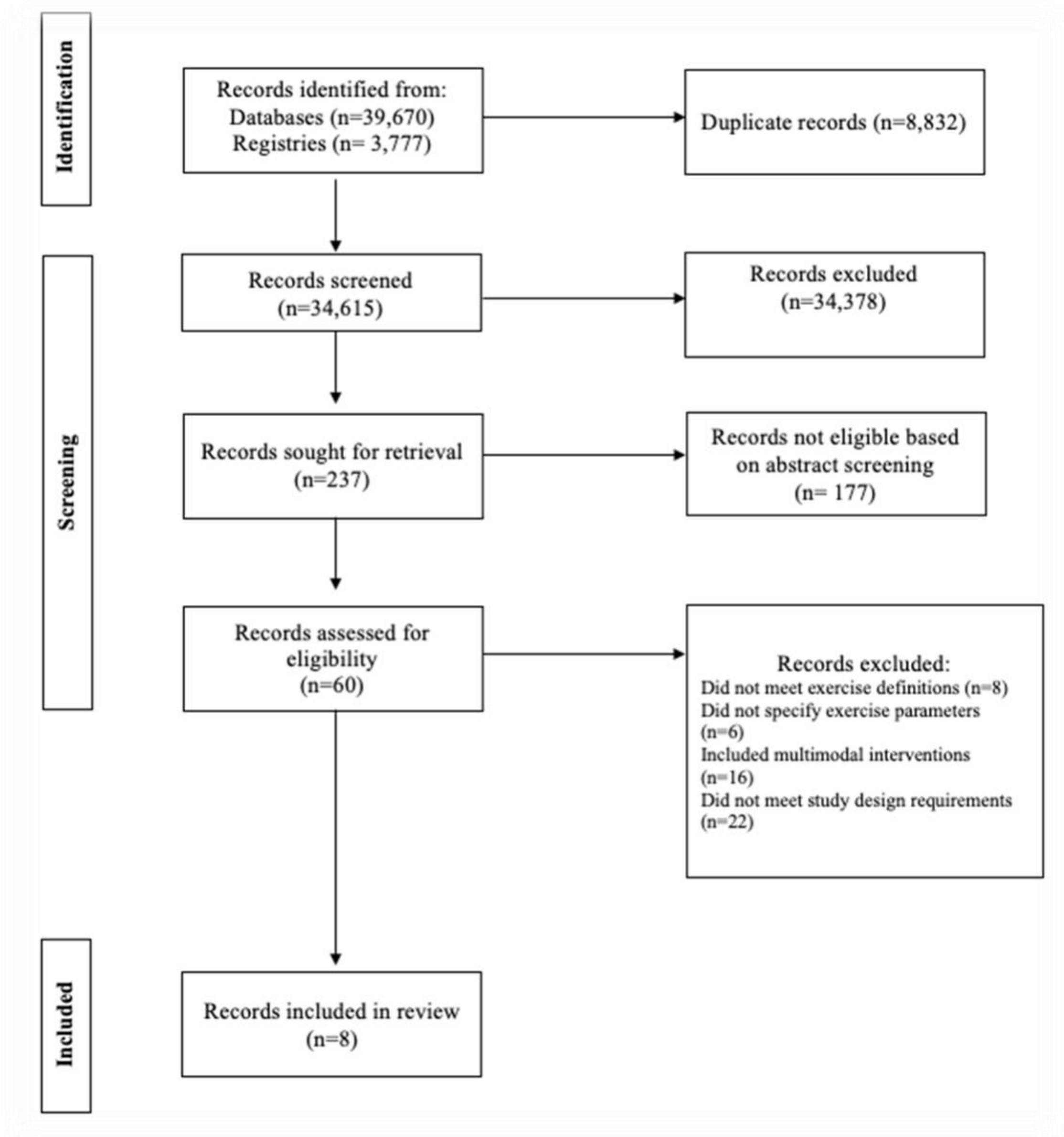
This systematic review was registered in the International Prospective Register of Systematic Reviews (PROSPERO database; see Appendix B) and was undertaken in adherence to guidelines of Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA). The approach was guided by an expert librarian, CH. Search terms such as "mTBI", "concussion", "post-concussion", "head injury", "minor head injury", "physical activity" and "exercise" were identified through team discussion, by trawling the thesauri and subject headings of the databases searched, and by investigating the language used in previous systematic reviews on similar topics. The precise keywords, subject headings and search syntax used in each database can be found in Appendix C.

The searches were run in the following databases: CINAHL (EBSCOhost), PsycINFO (EBSCOhost), MEDLINE (Ovid), Embase (Embase.com), SPORTDiscus (EBSCOhost), AMED - Allied and Complementary Medicine Database (EBSCOhost) and Cochrane Reviews (Cochrane Library). To find and include both negative results and the most up to date research, theses and clinical trial registries were searched on the ProQuest Dissertation & Theses Global database, Cochrane Central Register of Controlled Trials (Cochrane Library), ClinicalTrials.gov, UK Clinical Trials, Australian New Zealand Clinical Trials Registry, EU Clinical Trials Register and the WHO International Clinical Trials. Hand searching was performed on reference lists from relevant doctoral dissertations, prior systematic reviews, and the screened studies. The searches were carried out between 6-23 September 2019 and updated on 23-25 November 2020 to include recent publications. The term "posttraumatic symptoms" was recommended as an alternative term to post-concussion syndrome because of the non-specific nature of PPCS (Cassidy et al., 2014, p. 149). Thus, this term (and its synonyms) was searched from 2013 onwards.

Upon completion of the search process, two independent researchers carried out first level screening to remove duplicate articles and checked titles for suitability. This process was repeated for a second-level screening of full-text assessment. The screening sheet used for this process is included in Appendix D. A third reviewer was consulted if there were disagreements throughout the process. Figure 3.1 shows a PRISMA flow diagram of the screening process.

Figure 3. 1

PRISMA Flow Diagram for Systematic Review



3.2.2 Inclusion and Exclusion Criteria

The inclusion criteria were studies that: (1) were primary research, (2) were randomised controlled trials (RCTs), (3) included mTBI/concussion as the primary source of injury, (4) included post-concussion symptoms as an outcome measure, (5) included an exercise intervention that met the predetermined definition, and (6) used only exercise as a rehabilitation modality.

Studies that (1) were non-RCTs, (2) included moderate or severe traumatic brain injuries, (3) did not use exercise as an intervention, (4) were expert opinion and /or commentaries, (5) used exercise as part of multimodal rehabilitation, and (6) were not published in English were excluded.

3.2.3 Risk of Bias

Risk of bias (RoB) for all the studies was carried out using the Cochrane Collaboration's ROB-2 tool for RCTs (Sterne, 2019). Two independent researchers (KSJ and SK) conducted the RoB assessment and a third researcher (KS) was consulted if there was any disagreement. As outlined by the Cochrane guidelines, studies were assessed for the randomisation process, deviations from intended interventions, missing outcome data, measures of the outcome variable and selection of the reported results. The results from the RoB assessment are illustrated in Figure 2. Four studies were assessed to have an overall low risk of bias, three with high risk and one with some concerns.

Figure 3. 2

Risk of Bias Assessment for all the Reviewed Studies

3.3 Results

A total of 43 447 articles were identified. After duplicates were removed, a first level screening was done to omit irrelevant articles. The titles and abstracts of the remaining 237 articles were screened before 60 articles were selected for a full-text assessment. Of these 60 articles, a final eight studies met the inclusion/exclusion criteria for this review. Seven of these studies were journal publications and one was a doctoral dissertation (Kozlowski, 2008). Table 3.1 shows these eight studies with the key exercise parameters.

Table 3. 1

Studies Selected for Systematic Review in Chronological Order of Publication Year (Oldest to Newest).

		Exercise Parameters (FITTT)						
Study	N	Frequency	Intensity	Time (Duration)	Type	Time Post-Injury to start exercise (Mean)*	PCS outcome measures	PCS outcomes
Kozlowski (2008)	14 PCS vs. 10 non-injured controls	4 days/week; 21 minutes/session	80% max HR of baseline test	3 weeks	Treadmill, elliptical trainer, or stationary bike (participant's choice)	136 days (PPCS)	Graded Symptom Checklist; Head Injury Scale	No significant difference between groups; All PCS participants showed symptom reduction.
Maerlender et al. (2015)	15 usual care vs. 13 exertion	Daily for 20 minutes/session	0 to 6 on the Borg RPE[1] scale	Till symptom resolution	Stationary bike	2 days** (aPCS)	ImPACT scale; experimental scale to rate changes in symptoms during exercise	No significant difference between groups

Kurowski et al. (2017)	12 exercise vs. 14 stretching	5-6 days/week; Session duration based on baseline testing	80% of the duration during baseline test	7 weeks	Stationary bike	52 days (PPCS)	Post-concussion symptom inventory (PCSI)	Significant difference in symptom improvement on self-ratings but not on caregiver ratings. Improvements noted in both groups
Micay et al. (2018)	8 exercise vs. 7 usual care	2-day exercise, 1-day rest cycle; 20 minutes/session	50% age-predicted HR with progressive increases of 5% till 70%	11 days	Stationary bike	5 days (aPCS)	Post-concussion symptom scale (PCSS)	Significant within-group differences in both groups from baseline to 4 weeks but no significant difference in symptom report between groups

Leddy et al. (2019)	52 exercise vs. 51 stretching	Daily for 20 minutes/session	80% max HR of baseline test	30 days	Stationary bike or treadmill (walking/jogging if no access to gym)	5 days (aPCS)	Sport concussion assessment tool – 5th edition (SCAT 5)	Significant difference in recovery time where aerobic exercise group recovered faster than stretching group.
Chrisman et al. (2019)	19 exercise vs. 11 stretching	Daily; 5-10 minutes/session and increased weekly by 5-10 minutes till goal of 60 minutes/session	80% max HR of baseline test	6 weeks	Stationary bike, treadmill, fast incline walking, calisthenics (participant's choice)	49 days (PPCS)	Health Behaviour Inventory (HBI)	Significant effect of exercise observed with symptom improvement slower for chronic PCS (>9 weeks)
Snyder (2021)	13 aerobic exercise vs. 13 non-aerobic exercise vs. 10 healthy controls	6 days/week; 2 x 20 minutes with 5 min break/session	65%-75% of HR***	1 week	Stationary bike	20 days (aPCS)	Post-concussion symptom scale (PCSS)	No significant difference between groups; Symptom severity decreased for both aerobic and non-aerobic exercise groups.

Leddy et al. (2021)	61 aerobic exercise vs. 57 stretching	Daily for 20 minutes per session	Up to 90% max HR during baseline test	4 weeks	Walking, jogging, stationary bike (participant's choice)	6 days (aPCS)	Post-concussion symptom inventory (PCSI)	Patients assigned to aerobic exercise were more likely to recover within 4 weeks after injury compared with those assigned to stretching exercise, with a 48% reduced risk of persistent post-concussive symptoms in those who exercised.

Note. PCS=Post-concussion symptoms; HR =Heart rate

* The mean reported is only for the exercise condition and is rounded to the nearest number of days.
** This study only reported a median.
*** This study used a HR calculated using an equation by Tanaka et al. (2001).
[1] Borg's Ratings of Perceived Exertion

3.3.1 Participants

Among the reviewed studies, the average age of participants in five of the studies was approximately 15 years (Chrisman et al., 2019; Kurowski et al., 2017; Leddy, Haider, Ellis, et al., 2019; ; Leddy et al., 2021; Micay et al., 2018). The age of participants in another two studies ranged between 21 to 27 years (Kozlowski, 2008; Snyder, 2021). Maerlender et al. (2015) did not report any participant demographics except for stating that all participants were concussed college athletes. A larger proportion of participants were females and of White Australian ethnicity in three studies (Chrisman et al., 2019; Kurowski et al., 2017; Leddy et al., 2013). Micay et al. (2018) used only male participants.

Exclusion criteria for participants varied across studies; Maerlender et al. (2015) did not specify any criteria. Chrisman et al. (2019) did not report on comorbidity but excluded participants with cervical and vestibular related injuries. Kurowski et al. (2017) excluded participants with cervicogenic injuries and comorbidities. Three of the studies excluded participants with comorbidities (Kozlowski, 2008; Leddy et al., 2021; Leddy, Haider, Ellis, et al., 2019) while two included participants with comorbid issues (Micay et al., 2018; Snyder, 2021).

3.3.2 Injury Characterisation

Six studies measured post-concussion symptoms using self-reported symptom scales (i.e., Post-concussion Symptom Inventory [PCSI], Post-concussion Symptom Scale [PCSS], Sport Concussion Assessment Tool – 3rd edition [SCAT3], Health Behaviour Inventory [HBI]. Kozlowski (2008) used the Graded Symptom Checklist (CSC) and the Head Injury Scale (HIS). Maerlender et al. (2015) used a post-concussion neurocognitive test battery (ImPACT).

Six studies included participants with a history of 1 to 3 concussions, while Kozlowski (2008) and Maerlender et al. (2015) did not indicate concussion history. Five studies recruited participants with only sports related concussions; one study reported that most of their participants sustained injuries from sports (Kurowski et al., 2017) and two studies did not indicate mechanism of injury (Maerlender et al., 2015; Snyder et al. 2021).

3.3.3 Summary of Studies

There was considerable variation in the time post-injury in the reviewed studies with some including participants within days of a concussion. The average time from injury to commencement ranged from 2 to 52 days across the eight studies. As participants in six of the eight studies included adolescents, we defined PPCS using the longer cut-off for symptom persistence >28 days (Leddy et al., 2021), and aPCS as those presenting with acute symptoms ≤ 28 days since injury. It must be noted that adults are generally considered to be experiencing PPCS if their symptoms persist beyond a typical recovery period of 10-14 days (McCrory et al., 2017). The inclusion of both aPCS and PPCS studies was important to understand the overall benefits of exercise on symptoms after a concussion before differentiating its effect based on the duration of symptoms. Table 3.1 shows the eight reviewed studies — five studies on aPCS and three studies on PPCS — with the FITTT exercise parameters and other key findings.

3.3.4 Studies on aPCS

Maerlender et al. (2015) examined the suitability of exertion in recently concussed college athletes with an average time of two days after a concussion. The study compared the effect of moderate levels of exertion between 15 athletes receiving usual care and 13 athletes undergoing exertion tests till symptom resolution. Participants in this study exercised for 20 minutes during each session with gradual increments to intensity determined by the Borg's Ratings of Perceived Exertion (RPE) Scale. The average time to recover was 15 days for the exertion group and 13 days for the group receiving usual care. The study found no significant differences in time to recovery, concluding that exertional activities in early stages after a concussion were safe.

Micay et al. (2018) found that compared to baseline, an exercise regimen lasting 11 days (exercising every 2 days with 1-day rest) significantly reduced symptoms in participants 5 days post-injury. During the intervention, participants exercised for 20 minutes per session at 50% age-predicted HR with the intensity progressively increasing to 70% age-predicted HR over the course of the study. The study found the overall effect of the exercise program (*n* = 8) to be no different to a control condition that was provided usual care (*n* = 7).

Leddy, Haider, Ellis, et al. (2019) compared the effect of a 30-day exercise program using an aerobic exercise condition (*n* = 52) and a stretching control group (*n* = 51). Participants initiated the study at an average of 5 days post-injury, exercised daily for 20 minutes per session and at 80% of the HR achieved during baseline tests. Participants in the aerobic exercise group recovered significantly quicker in a median of 13 days as compared to those in the stretching condition who took a median of 17 days to report symptom reduction.

Snyder (2021) investigated the safety and effectiveness of a 1-week exercise program (i.e., 6 days of exercise with 1 rest day) for participants at an average of 20 days post-injury. Participants were required to exercise for two 20-minute sessions with a 5-minute break between each session, and at 65-75% of the heart rate (HR) achieved during baseline tests. The study used three conditions: aerobic exercise intervention (*n* = 13), non-aerobic exercise intervention (*n* = 13), and non-injured control (*n* = 10). While there was no significant difference in PPCS outcome between the three conditions, the author reported decreasing symptom severity for both exercise and non-aerobic exercise conditions.

Leddy et al. (2021) compared the effectiveness of an individualised subsymptom threshold aerobic exercise program (*n* = 61) with a stretching control group (*n* = 57) among adolescent athletes within 10 days post-concussion. Participants in the aerobic exercise condition were more likely to recover within the 4-week intervention period and were found to have a reduced risk of PPCS at the end of the intervention.

3.3.5 Studies on PPCS

Kozlowski (2008) studied the effects of an aerobic exercise program on PPCS participants (*n* = 14) and age and gender matched non-injured controls (*n* = 10). Participants in the PPCS group were symptomatic at 136 days post-injury. The exercise program required participants to exercise for 4 days each week, for 21 minutes per session and at 80% of the maximum HR achieved during baseline tests. The study found no differences in physiological measures (i.e., heart rate variability, balance tests) between the two experimental groups after the initial study duration of 3 weeks. However, an extension of the program for up to 10 weeks indicated a trend of fewer and less intense symptoms in those with PPCS.

Using a 7-week aerobic exercise program, Kurowski et al. (2017) assessed self-reported and caregiver symptoms in an exercise group (*n* = 12) as compared to a stretching control group (*n* = 14). Their exercise program entailed 5-6 days of exercising each week with the duration and intensity of each session determined by baseline tests. Over the course of the study, improvements were noted in both groups. A significant improvement in symptoms was noted in the self-reported measure, but not in the ratings from caregivers. This was the only study in this review that reported an effect size (*d* = 0.51).

Chrisman et al. (2019) compared an exercise group (*n* = 19) with a stretching control group (*n* = 11) using a 6-week aerobic exercise program. The participants initiated the exercise program with daily exercises lasting 5-10 minutes per session. The duration of each session was increased weekly by 5-10 minutes till the goal of 60 minutes of daily exercise was reached. The intensity of exercise was 80% of the HR achieved during baseline tests. A significant effect of the exercise was observed but symptom improvement was observed to be slower for those with PPCS for 9 or more weeks.

3.3.6 Effects on aPCS and PPCS

Of the eight studies, four studies reported a significant between group difference in symptom improvement because of the exercise intervention (Chrisman et al., 2019; Kurowski et al., 2017; Leddy, Haider, Ellis, et al., 2019; Leddy et al. 2021). Of these, two studies used participants with aPCS (Leddy, Haider, Ellis, et al., 2019; Leddy et al., 2021) while two included participants with PPCS (Chrisman et al., 2019; Kurowski et al., 2017).

Micay et al. (2018) did not find a significant difference between groups, but the authors observed more pronounced symptom resolution in the exercise group and reported improvements in symptoms from baseline in both the exercise and usual care group. In the Maerlender et al. (2015) study, participants in the exercise group were noted to have prolonged recovery, although this was not significantly different to the control group. Kozlowski (2008) and Snyder (2017) did not find any significant effects of the exercise intervention between experimental conditions but noted overall symptom reduction in those who exercised.

3.4 Discussion

The aim of this systematic review was to investigate whether exercise rehabilitation was effective and if so, identify a set of clearly defined exercise parameters that have demonstrated positive outcomes for PPCS. Only RCTs were selected as these are considered the best type of evidence for addressing questions about health-based interventions (Ryan et al., 2013). The first research question (**RQ1**) addressed whether unimodal exercise rehabilitation was effective for PPCS based on RCTs and found evidence in favour of exercise for PPCS via between-group differences (i.e., treatment versus control). Notably, between-group differences showing improvement over time were observed in four studies: two studies on aPCS and two studies on PPCS. This suggests that exercise can have a positive effect on PCS[2] regardless of symptom duration. However, the absence of an interaction in several studies also suggests the possibility of spontaneous remission or recovery. Further, the fact that only four of the eight studies found between-group differences (exercise vs. control) highlight the need for cautious interpretation, and warning against overstating the benefits of exercise for PCS.

The second research question (**RQ2**) was to identify the parameters (i.e., FITTT) of unimodal exercise programs for PPCS. This was expected to guide future research and program development. The review found that, despite differences in injury profiles across participants in eight studies (aPCS vs. PPCS), similar exercise parameters were used in the interventions and no safety issues were reported. Therefore, to summarise these parameters, the data was pooled across studies.

3.4.1 Optimal Exercise Parameters (FITTT)

Frequency of Exercise

There is support in this review for the frequency of exercise to range from 4-7 days in exercise programs for PCS. Most studies used protocols ranging from 5-7 days except for Micay et al. (2018). Although Kozlowski (2008) did not find any significant effect in an exercise program that involved exercising for four days, the program duration in this study was shorter than most other studies (i.e., 3 weeks). A closer inspection of the data on compliance to the exercise intervention in Kurowski et al. (2017) suggested that participants in the exercise group took part in approximately 4 days of activity each week. The significant reduction in symptoms and a moderate effect size (d=0.51) in this study suggests that commencing exercise programs at 4 days a week could confer similar benefits to programs requiring more frequent exercise.

[2] The term “PCS” is used to refer to both acute (aPCS) and persistent (PPCS) post-concussion symptoms hereafter. Separate terms are only used to differentiate these sub-groups where relevant.

The studies reviewed suggest that exercising for 20 minutes per session is the most common and effective approach. However, Chrisman et al.'s (2019) progressive approach of starting at 5-10 minutes per session and working up to a maximum of 60 minutes could have practical benefits (e.g., acculturating participants into the program, or if used with goal setting). Further adaptations to limit the goal of such progressive exercise sessions to 20 minutes excluding time taken for warm-up and cool-down could be one possibility that is better aligned to the other reviewed studies. These progressive increments are arguably more palatable and safer for those who are less conditioned. Another less common option was to use baseline tests to determine session durations based on symptom exacerbation as done in Kurowski et al. (2017). While this approach is more personalised, it can be resource intensive.

Intensity of Exercise

Exercise intensity is a vital parameter to ensure that the activity can achieve an intended physiological outcome (Garber et al., 2011). This is especially important for PPCS rehabilitation given suggestions that the increased cardiovascular activity leads to restoration of deficits incurred after a concussion. While some studies used age-predicted HRs[3] ranging from 50%-75% (Micay et al., 2018; Snyder, 2017), it was more common for participants to exercise at 80% HR of the subsymptom threshold[4] during a baseline test (Chrisman et al., 2019; Kozlowski, 2008; Leddy, Haider, Ellis, et al., 2019). Leddy et al. (2021) prescribed a protocol based on 90% of the maximum HR during the baseline BCTT test and found positive effects but participants in this study were adolescent athletes with aPCS.

Two studies did not use HR measures. Maerlender et al. (2015) used Borg's Ratings of Perceived Exertion Scale (RPE) while Kurowski et al. (2017) asked participants to

[3] The age-predicted HRmax equation (i.e., 220-age) is commonly used as a basis for determining an age-specific criterion for measuring maximal exertion during diagnostic exercise testing (Tanaka et al., 2001).
[4] The sub-symptom threshold is determined by the heart rate that provokes symptoms during baseline exercise testing (McIntyre et al., 2019).

exercise for 80% of the *duration* in which symptom exacerbation occurred during a baseline test.

The evidence from this review suggests that exercise can benefit PCS when offered at an intensity of 50% age-predicted HR. Although higher intensity programs are more commonly used, this intensity could be an appropriate *starting* point for some populations (e.g., non-athletes). If using baseline tests, working up from a lower subsymptom threshold HR of 50% - depending on patient response – could also support a more calibrated approach. For fitter adolescent athletes, a higher threshold of up to 90% of the HR during baseline testing can be further explored. Additionally, objective measures such as HR should be complemented with subjective measures of intensity such as the Borg's RPE for a more comprehensive monitoring of intensity and patient response.

Time (Duration) of Exercise

Among the reviewed studies, programs that lasted for less than a month did not demonstrate beneficial effects (Kozlowski, 2008; Snyder, 2017). It is possible that such short duration programs lacked the exercise dose required for restoration of physiological mechanisms implicated in PPCS (Leddy et al., 2016). In this review, reduction of symptoms was observed as early as four weeks in five of the studies (Chrisman et al., 2019; Kurowski et al., 2017; Leddy, Haider, Ellis, et al., 2019; Leddy et al., 2021; Micay et al., 2018).

Micay et al.'s (2018) unconventional 11-day regimen led to longer term benefits for up to four weeks, but the program intensity (minimal rest days in this period) and application in a small, selected sample of athletes with acute symptoms (5 days post-injury) make it difficult to determine if this approach would be practical for other groups. Maerlender et al. (2015) adopted an approach whereby the program was extended only when those with aPCS experienced delayed recovery beyond a predetermined time period. The two adolescent PPCS studies offered programs lasting six (Chrisman et al., 2019) or seven (Kurowski et al., 2017) weeks. Snyder et al.'s (2021) intervention for adult PPCS lasted one week with no significant effects across experimental groups.

Taken together, this review found significant variation in program duration (from one to seven weeks), but effective programs typically lasted at least four weeks. The two aPCS studies by Leddy et al. on adolescents reported benefits of exercise after a week, while the two PPCS studies (Chrisman et al., 2019; Kurowski et al., 2017) on adolescent participants reported symptom reduction after four weeks of exercise. This review establishes that the ideal program duration will depend on when the program can be delivered (acute or chronic phase) and its focus (e.g., resolution of aPCS or management of PPCS). Individual factors, such as personal motivation, general health, and fitness, as well as overall program attributes will also require consideration when selecting program duration. The duration of a program for PCS could also be individualised. For example, it could last from 1 to 4 weeks (or longer, if required), include adjustments (e.g., progressive intensity, if required) and would be discontinued when a recovery goal was reached (e.g., medical clearance for return to play, reduced symptomatology).

Type of Exercise

Most exercise programs in the reviewed studies involved aerobic exercising on treadmills or stationary bikes. A pragmatic rationale was often given, such as to minimise injury risks or better monitor symptoms (Worts et al., 2019). While this may be crucial for baseline testing, more recent studies in this review such as Chrisman et al. (2019) and Leddy, Haider, Ellis, et al. (2019) gave participants a choice of exercise. Chrisman et al. (2019) allowed participants to change the modality according to their preferences (e.g., exercise bike, treadmill, fast walking up an incline/stair, or calisthenics). In line with principles of exercise physiology, if exercise intensity and duration are key factors to elicit favourable change for PPCS, any aerobic or cardiovascular activity under safe conditions should grant similar benefits. Given the better compliance and increased enjoyment observed with a choice of activity in the Chrisman et al. study, future exercise programs can consider a range of aerobic activities with the suggested parameters guided by baseline tests and monitoring in the initial stages. Program planning can then consider recommending subsequent sessions that are home-based with a larger variety of activities after potential risks are assessed.

Time Post-Injury

The period that should pass before a concussed individual can safely exercise has been an equivocal issue in PCS research. Current consensus is for a resumption of selected activities after an initial 24-48 hours of rest. The recommendation is for activity to be progressively increased over a 7-to-10-day period until it returns to usual, or the process discontinues if there is symptom exacerbation (McCrory et al., 2017; Schneider et al., 2017). While findings from this review suggest that exercise can offer moderate benefits for aPCS if undertaken 2 to 20 days post-injury, these studies primarily involve adolescent athletes. When considering the three studies on PPCS, the time between injury and commencement of exercise varied substantially (i.e., 49-136 days), with symptom improvements observed in two studies (Chrisman et al., 2019; Kurowski et al., 2017). While there is evidence from the literature (Reid et al., 2022) and this review that exercise can be safe and beneficial for those with symptoms in both acute and more chronic stages, the ideal period to commence exercise for PCS in wider populations requires further study. More importantly, appropriate baseline tests and medical advice should precede any advice to exercise after a concussion.

3.4.2 Practical Considerations

First, it is imperative to note that studies in this area have typically used small and restricted samples, lacked indication of an effect size, and possibly allowed variation in several personal and injury related variables (e.g., injury perception, type of injury). This is understandable as the purposes of these studies could vary from testing the safety of a protocol to evaluating the efficacy of specific parameters in specific populations. Coupled with the fact that natural recovery can also contribute to symptom improvement, it is essential to compare any beneficial effects of exercise with appropriate control conditions and ensure not to overgeneralise findings from studies intended for different purposes.

Second, the exercise parameters recommended in this review for consideration in future studies or exercise rehabilitation programs are not intended to be prescriptive. Instead, this review consolidates exercise parameters from a high-quality evidence base to aid further research and development of exercise interventions. This review highlights the need for more well-designed, representative, and large-scale studies on exercise for PCS. If such programs are to be trialled in wider populations, such as non-athletes or older adults, the lower end of the effective range of the FITTT parameters can be considered in programming decisions (e.g., commencing aerobic exercise of choice at 50-60% HR of symptom threshold for 10-15 minutes in a program of between 1 to 4 weeks duration), preceded by the standard medical checks.

Third, it is useful to adopt a pragmatic approach when using some of these exercise parameters. While the fundamental principles of an individually tailored subsymptom threshold exercise should be the cornerstone of such interventions, time constraints and pre-existing fitness levels can be influential factors that determine compliance and attrition. For example, commencing programs at 4 days a week for 10-15 minutes with gradual increments to intensity, enrolling individuals in exercise programs only for the duration necessary for clinical recovery (e.g., return to work, pre-injury status), and giving them a choice of aerobic activities are possible ways to maintain motivation and improve participation rates in such exercise programs. A recent proposal by Chrisman et al. (2022) describes the use of a patient’s age and sex to determine the HR for moderate to vigorous exertion. Such initiatives to tailor interventions and consider the preferences of participants are important to initiate and keep individuals who are less conditioned or time poor in such exercise programs. Commencing programs at lower and more manageable intensities can also improve confidence and allow enjoyment in the activity, all factors that can upkeep participation (Yang, 2019). Consideration of other individual factors such as motivations and perceptions about exercise is also encouraged and could extend to research in new directions and help achieve translatable progress.

Lastly, six of the eight reviewed studies prescribed home-based programs after the initial baseline tests. While this approach allows for an evaluation of the safety of the program in the initial stages before providing the convenience of exercising at home, considerations for group-based exercises using the recommended parameters can also be made. Group based exercises have shown to improve mental and subjective well-being (Harada et al., 2019; Kanamori et al., 2016), increase social support and enjoyment (Stevinson & Fox, 2005), and result in better clinical outcomes in various settings (King et al., 2015). Interacting and exercising with others experiencing PPCS could also help to normalise such an heterogenous and complicated issue and help patients learn coping strategies from one another. The decision to prescribe home-based individual programs or gym-based group programs will have to be made by researchers/clinicians after careful consideration of resources available and individual preferences. Table 3.2 summarises the exercise parameters recommended from this review.

Table 3. 2

Recommended Optimal Exercise Parameters (FITTT)

Frequency	Intensity	Time (Duration)	Type	Time Post-Injury (Mean)
Starting with 4 days/week and increase based on patient response. Starting from 10-15 minutes and progressive increments tailored to individual fitness	Starting with 50% and up to 80%-90% sub-symptom HR during baseline test Complemented with subjective measures (i.e., Borg's RPE)	Up to 1 week till asymptomatic, whichever is sooner. Program can be customised to individual needs and extended for those with delayed recovery.	Participant choice with adherence to prescribed guidelines. Close monitoring strongly recommended in early stages.	After 24-48hrs of rest and suitability assessed through a baseline test*

*****This is based on studies limited to athletes and adolescents. Further studies are required to determine time to commence exercise rehabilitation in different population groups and symptom profiles

3.4.3 Future Directions

With much of the focus on aerobic exercise, future studies can explore other types of activity that can potentially achieve similar benefits. In this review, Snyder (2017) was the only study that included a non-aerobic exercise group participating in low-intensity static stretching and callisthenic movements. Interestingly, the study found that the cumulative effect of both aerobic and non-aerobic exercise on symptoms was similar after 7 days, and a longer program duration could have offered better insights on the potential of non-aerobic interventions. Sullivan et al. (2018) recommended a new approach underlying principles of an individualised subsymptom threshold program but with combined aerobic-resistance exercise for those with PPCS. While there is yet to be a controlled trial examining this exercise protocol, parameters from this review could be integrated in future trials to assess the benefits of such novel programs.

Considering the heterogeneity and non-specific nature of PPCS, future research can explore the benefits of different combinations of exercise parameters on individual risk and injury-related factors. Evaluating and comparing the effects of different parameters (e.g., 50% vs. 80% HR of subsymptom threshold) can lead to streamlined suggestions for subsequent exercise interventions. Implementation studies can also take the form of comparing whether increasing a particular parameter (i.e., intensity) can lead to similar benefits with other parameters kept constant or changed (i.e., similar or shorter program duration). These studies can also be useful to investigate whether specific exercise protocols have better compliance than others. It is also common for studies to examine short term effects of exercise, but some findings suggest that the accrued benefits of exercise can be lost in 1-2 weeks upon cessation of exercise (Garber et al., 2011). Future studies can investigate the longer-term effects of exercise using the recommended parameters.

The lack of well-designed, representative, and large-scale studies on exercise rehabilitation is also apparent from this review. The risk of bias assessment used in this review suggested that methodological issues were still present in RCTs exploring effectiveness of exercise for PPCS. High attrition rates and specific inclusion criteria add to the challenges in PPCS exercise research. In the studies used in this review, recruitment rates were less than 35% for three of the studies (Chrisman et al., 2019; Maerlender et al., 2015; Snyder, 2017), and two studies did not report attrition rates (Kozlowski, 2008; Leddy et al., 2013). Recruitment rates for PPCS studies can be lower due to patients recovering between the time they are contacted for participation and potential enrolment into the study. Future studies should consider investigating the recommended parameters with better recruitment, more rigorous methodological approaches (e.g., use of accelerometers to monitor activity), and a greater representation of more diverse population groups.

3.4.4 Strengths

A strength of this systematic review is the use of a rigorous approach to select only studies with exercise interventions. This permitted an evaluation of the potential effects of exercise on PPCS outcomes without the possible confounding effects of other rehabilitation modalities.

While the evidence for exercise is observed to be moderate in this review, the identification of a set of well-defined parameters is unique to this study and is expected to make a meaningful contribution towards exercise rehabilitation research for PPCS.

3.4.5 Limitations

This review used a very stringent criterion of only including RCTs. While reviewing controlled studies with exercise interventions resulted in specific effects attributable to exercise, effective exercise parameters that were a part of multimodal interventions or from non-RCTs (e.g., cohort studies, case series) could have been excluded.

The suggested PCS exercise parameters from this review are speculative, based on aggregated findings, and represent an attempt to identify a “minimum effective dose” of exercise for PCS. The effect of combining these specific parameters remains unknown and requires further testing. These parameters emerged from studies that mainly included adolescent athletes and this introduces a bias (e.g., athletes may be more adept at tolerating exercise-based interventions than other groups, the results could be contaminated by a prior fitness or conditioning effect, different timelines would apply to distinguish aPCS from PPCS in different population groups). A program designed with these parameters could be poorly tolerated in other groups. Future studies need to more closely investigate the feasibility and safety of such exercise programs across more diverse age groups and/or symptom profiles.

Further considerations in such studies include closer examination of the influence of other demographic and injury related factors on exercise and recovery. For example, a considerable proportion of participants in the reviewed studies were athletes, highlighting a possibility that prior fitness or conditioning could be playing a protective role that accentuated the effects of exercise. Prior fitness and exercising have been demonstrated to be protective factors in animal studies (Gu et al., 2014; Lima et al., 2009) and concussed individuals (Leddy et al., 2010; Snyder, 2017) and more studies exploring such effects are warranted.

A further limitation of this review is that the recommendations are largely drawn from a relatively small pool of studies with small samples. Large variations in injury profiles were noted, and studies generally lacked the power to offer conclusive findings. This review found significant variation in key aspects of the research, including the timing of the intervention, selection of outcome measures and exercise protocol. Due to these factors, it was not possible to complete a formal comparative analysis (e.g., meta-analysis), but this should be considered as the literature grows.

3.5 Conclusion

The past decade has led to a shift in consensus that prolonged rest may not be beneficial for PPCS and progressive exercise after an initial period of rest can be useful. While there has been a surge in studies investigating the efficacy of exercise for PPCS rehabilitation, much ambiguity has remained around specific exercise parameters that could be examined in larger studies and in wider population groups. Based on high-quality evidence, this review shows promise for the effectiveness of exercise to treat PPCS. It is recommended that the identified set of exercise parameters be adopted in further research to guide future clinical applications.

3.6 Chapter Summary

This chapter explored whether exercise rehabilitation for PPCS was effective and if findings support the adoption of such rehabilitation for the community. If there was sufficient support for exercise for PPCS, a secondary aim was to identify a set of clearly defined exercise parameters for future research and clinical considerations. A systematic review of studies that only investigated exercise rehabilitation revealed moderate support for exercise, but these were based on studies with adolescents and athletes. To facilitate the replication of exercise studies in wider populations and further rehabilitation research for PPCS, the following exercise parameters were identified. Based on the reviewed studies, exercise rehabilitation, at a minimum, can commence at 4 days a week, with each exercise session lasting 10 minutes, and at intensity of 50% sub-symptom threshold HR (during baseline tests). Any modality of exercise that increases cardiovascular output in a safe manner is acceptable. While benefits of exercise rehabilitation was found in both the acute and persistent phases of PCS in a handful of studies, further research on wider population groups is necessary to inspire greater confidence in such rehabilitation for the community. The identified parameters are nevertheless the first step towards considering such potentially beneficial PPCS rehabilitation programs for everyone affected by this debilitating condition. Further work is needed to test the effectiveness of programs designed according to these parameters and this can move the field closer to consensus guidelines for translation to the wider community.

Chapter 4 – Knowledge and Attitudes about Concussion and Rehabilitation in an Australian Community Sample

4.1 Chapter Introduction

This chapter will focus on Study 2; the aim of which was to explore the knowledge and attitudes about concussion and rehabilitation in an Australian community sample. While Study 1 examined the effectiveness of exercise rehabilitation for PPCS and identified a set of exercise parameters for future research, there are still unanswered questions around whether people recognise the need for such rehabilitation. Rehabilitation options will only be considered by individuals when they know enough about the potential consequences of post-concussion symptoms. Moreover, behaviour change theories support that, to some extent, knowledge can shape attitudes that in turn lead towards risk reduction behaviours and better adoption of management strategies in various health contexts (Bandura, 2004; Williamson et al., 2021). While existing research has focused on knowledge and attitudes about concussion and management of symptoms in sports communities[5], similar information about the general community is unclear. Investigating how much people in the community know about and what their attitudes are towards concussions and rehabilitation can provide insights into developing future education and intervention programs and could enhance or improve uptake of rehabilitation programs.

The impact of concussions and PPCS has been established in the earlier chapters. To further put this into perspective, it is estimated that up to 69 million individuals will suffer from TBI from all causes each year, with Southeast Asian and Western Pacific regions experiencing the greatest burden of disease (Dewan et al., 2018). With the largest proportion of such injuries being concussion as opposed to more severe TBIs, understanding, and managing these injuries is important. For those who go on to develop PPCS, effective

[5] Sports community is used to describe athletes and coaches/athletic trainers.

rehabilitation can minimise economic costs by reducing healthcare usage and loss of productivity. An argument put forward in this thesis is that the lack of knowledge and misinformed attitudes about concussions and rehabilitation could contribute to poor adoption of potentially useful options like exercise. While there are initiatives in place to educate individuals on recognising concussion symptoms and correct misconceptions (Caron et al., 2015; Caron et al., 2018; Perlin & Kroshus, 2020), concussion knowledge still appears to be inadequate. A systematic review by Yeo et al. (2020) found significant knowledge gaps, particularly with less common post-concussion symptoms and misconceptions about management and prevention of concussion. Identifying specific gaps in knowledge and understanding how attitudes need to shift can contribute effectively towards public education programs. The development and continual improvement of existing education programs is a key management strategy that has been recommended in the literature (Kerr et al., 2021; Salmon et al., 2020), including in Australia (Elkington et al., 2018).

Most research on concussion knowledge and attitudes has focused on athletes, coaches, and parents (Waltzman & Daugherty, 2018). Studies on these sports communities have provided useful insights on how knowledge and attitudes shape athlete behaviour. For example, a large proportion of athletes underreport their injuries (Anderson et al., 2016; Martin et al., 2017; McCrea et al., 2004; Sefton, 2003) and this has been attributed to a lack of injury awareness, (Chinn & Porter, 2016; McCrea et al., 2004), underestimating the seriousness of injuries (Delaney et al., 2015; Sefton, 2003), social pressure (Kroshus et al., 2015), and the likelihood of losing incentives (e.g., scholarships) linked to sports participation (Bauman, 2005). A systematic review found education to improve concussion knowledge scores and reporting behaviour in general (Beran & Scafide, 2022), but athletes still continue to underreport due to a fear of losing the opportunity to continue playing (Kroshus et al., 2020). Simlarly, having a history of concussion was also not associated with better knowledge, safer attitudes, or increased reporting behaviour because of negatively perceived concussion experiences or the consequences of being removed from play (Beran & Scafide, 2022; Kroshus et al., 2020; Register-Mihalik et al., 2017). Through the understanding of such factors, education programs have been tailored to improve symptom identification and understanding the potentially harmful consequences of continuing to play a contact sport while symptomatic (e.g., re-injury, second impact syndrome). However, such initiatives directed at the sports community alone may not necessarily translate to better knowledge and safer concussion attitudes towards management or help seeking practices. A more concerted effort to reach out and educate the community that includes sports fans, doctors, and the media is necessary.

Extending research on concussion knowledge and attitudes to the wider community is important because concussion is not limited to athletes. It is estimated that only around one-fifth of concussions are caused by sports-related injuries (Clark & Sirois, 2020), but this could be an underestimate when considering patients who are not seen at hospitals. While the risks of contact sports make it understandable for research to focus more on sports-related concussion, people in the community can also sustain similar injuries through non-sports related causes (Hon et al., 2019). For example, the Centers for Disease Control and Prevention reported that common causes of concussions are falls, motor-vehicle accidents and assaults (CDC, 2022). Those with a concussion from a motor-vehicle accident can experience different types of injuries with the potential for other issues such as whiplash injuries and post-traumatic stress disorder. While mechanisms of injury can vary depending on how the information is recorded (e.g., recreational injures being recorded as sports-related), the wide possibilities of how concussions can occur, and the consequences resulting from different injury mechanisms (e.g., falls, motor-vehicle accidents, assault) highlight the need for comprehensive concussion education for the community. Better symptom identification, clarification of misconceptions, awareness of persistent symptomology, and effective rehabilitation options can be important areas to focus on for community education program.

It can be argued that current awareness programs are sufficient, and the increasing media coverage of contact sports could have indirectly improved concussion knowledge of the general community (Slobounov et al., 2014), but the outlook based on the few studies in the general community may give reason to pause. For example, a North American study found that while most people in the community knew about causes of concussions, there was uncertainty regarding the possibility of symptoms in multiple domains (Waltzman & Daugherty, 2018). Mannings et al. (2014) observed that while knowledge was high in a North American sample, several misconceptions about concussions persisted. Kerr et al. (2020) noted that up to one-third of North American parents of children participating in sports did not seek advice from credible sources like doctors/healthcare providers for concussion related information. These limited findings highlight the paucity of research in the general community and that past work in this area has focused on sports communities (e.g., coaches, parents, athletes). While some of these initiatives could have improved concussion literacy to a certain extent, there is much more work that needs to be done for those in the general community.

The importance of understanding the current level of concussion knowledge in the general community may be underscored if some contextual factors are considered. For example, it has been argued that members of the community, particularly fans of contact sports, could be exposed to incorrect or trivialising information about concussion from media coverage on sports (Kollia et al., 2018). This is further supported by McLellan and McKinlay (2011) who found that the media was a common source of concussion knowledge for the public, sometimes in a weekly basis of sports telecast. A follow-up study specified that media commentary focused on the way the injury was sustained, but information about players receiving medical attention was rarely conveyed (Kennard et al., 2018). Schwartz (2017) studied the impact of injury description in the media and found moderate support for participants acknowledging the severity of concussions based on the written commentary of the injury. More recently, Ku et al. (2020) investigated if the media portrayal of concussions led to a lack of public understanding of concussions in Australia, New Zealand, and the United Kingdom. The study found that media commentary about an injured player's return-to-play decision significantly influenced decisions on severity of injuries. For example, if the commentary suggested that a player was allowed to return to play after an injury, the participants were less likely to judge the injury to be serious. These findings highlight the importance of community education about concussion and how the media can be a powerful tool behind changing attitudes and perceptions regarding the injury and managing it.

With increasing attention on concussion given to athletes, coaches, and parents because of the potential risks in contact sports, knowledge is expected to have improved in these groups (Sarmiento et al., 2017). However, gaps are still evident in the type of knowledge reported by these groups (Perlin & Kroshus, 2020). White et al. (2014) pointed out that key messages from management guidelines such as the risks of second impact syndrome and variations in symptom presentations were not reaching sports coaches and trainers. A recent review found concussion knowledge to be only moderate among coaches and sports officials (Yeo et al., 2020). Feiss et al. (2020) highlighted that coaches were still unaware of important details such as time taken to recover after a concussion while parents lacked knowledge regarding concussion management and return-to-play guidelines. The lack of comprehensive coverage of important issues surrounding concussion is evident in this area of research. Given that knowledge gaps are still noticeable among groups associated with regular exposure to concussion education, there is a greater need for tailored and extensive concussion education programs for the community that do not usually have similar access to such programs.

It is unclear if the knowledge gaps observed in the literature on concussion knowledge can be attributed to current modes of training delivery or type of content covered in the education. A review of existing education materials for the general community indicates an emphasis on injury definitions, long and short-term sequelae and return-to-play decisions (Feiss et al., 2020). While the CISG consensus statement advises gradual return to play for adults within 7 to 10 days post injury, the need for a brief period of rest (i.e., 1-2 days) and for rehabilitation to be individualised (McCrory et al., 2017), these recommendations are currently not reflected in detail in post-injury advice for the public. While athletes may be better supported by coaching and medical staff after an injury, the general community may be left to obtain such information on their own unless they seek specific medical assistance. This omission of rehabilitation options (e.g., psychological therapy, exercise) in public education materials is striking especially considering the risk of PPCS being similar for both sports and non-sports related concussions. It is thus logical to investigate how much the community knows about concussions, what their attitudes are towards such injuries and what they know about evidence based PPCS rehabilitation. Identifying any gaps in these areas may be useful to enhance current education programs, encourage participation in emerging evidence-based practices and steer opinions away from the traditional and now unsupported approach of prolonged rest.

To date, there are no studies exploring concussion knowledge, attitudes, and awareness of rehabilitation approaches in an Australian community sample. While some studies have addressed parts of this question (Hecimovich et al., 2016; Kinmond et al., in press), this has been in highly selected samples, and aspects such as awareness of rehabilitation options, and in particular if exercise could be useful, have not been previously explored. Hecimovich et al. (2016) investigated concussion knowledge in an Australian study but limited the study to only Australian Rules football players and parents. Kinmond et al. (in press) investigated predictors of concussion knowledge in the Australian community but did not include measures of attitudes towards concussion. This study will investigate concussion knowledge, attitudes, and awareness of current rehabilitation recommendations in an Australian community sample. Since previous studies have shown that some members of the community, such as those involved with contact sport, may have had more resources on concussion knowledge than others (Kerr et al., 2021), group differences in concussion knowledge and attitudes were also explored. If group differences are found, this could help to guide education efforts to address specific gaps.

4.2 Research questions

To determine the levels of current knowledge and attitudes in the general community without prior exposure to concussion education, the study distinguished groups with and without prior self-reported concussion education. Next, as a prior concussion should present individuals with the opportunity to receive post-injury advice including what to do for their recovery, this was another variable of interest. Finally, as there is yet to be a study that explores how much people in the community know about their options for rehabilitation if experiencing PPCS, this study explored what were common recommendations that people knew about and whether exercise was offered as advice. The study had the following 7 hypotheses (i.e., H3-H9):

H3*: Participants who play contact sports would have higher levels of concussion knowledge than those who do not play contact sports.*

H4: *Participants who play contact sports would have safer attitudes towards concussion than those who do not play contact sports.*

H5: *Participants with prior concussion education would demonstrate higher levels of concussion knowledge than those without prior education.*

H6: *Participants with prior concussion education would demonstrate safer attitudes towards concussion than those without prior education.*

H7*: Participants with a prior history of concussion would demonstrate higher levels of knowledge than those without a previous injury.*

H8*: Participants with a prior history of concussion would demonstrate safer attitudes towards concussion than those without a previous injury.*

H9: *What are some of the common advice provided for recovery after a concussion?*

4.3 Method

4.3.1 Participants

An online survey was completed by 224 participants ($M_{age} = 21.5$, $SD_{age} = 7.6$, females =78%). The sample included members of the general community recruited via social media advertisements, researcher contacts and students from a first-year research participation pool of a large metropolitan university in Queensland, Australia. All recruits were encouraged to share the study details within their networks (i.e., snowball sampling). The inclusion criteria were as follows: (a) aged ≥ 18 years; (b) resident in Australia at the time of the study; and (c) provided valid responses (see below). A total of 254 participants completed the survey and 30 ineligible participants were removed prior to data analysis (i.e., ≤ 17 years, $n = 22$; failed validity scale, $n = 4$; non-Australian resident, $n = 4$), ($M_{age} = 21.8$, $SD_{age} = 7.5$, range 18-76 years; females =78%).

Participants were further divided into sub-groups for selected analysis by their responses to the following "yes/no" questions. To identify history of concussion, the question, "*Have you experienced a concussion in the past?*" was asked with follow-up questions on number of concussions if a history was reported. Sports participation was determined by the question, "*Do you play contact sports?*" and prior concussion education was assessed by the question, "*Have you studied or been taught about concussion?*".

4.3.2 Measures

Concussion Knowledge

The Rosenbaum Concussion Knowledge and Attitudes Scales (RoCKAS) consists of 55 items and is divided into 5 sections (Rosenbaum & Arnett, 2010). Concussion Knowledge is assessed in Section 1, 2 and 5. Sections 1 and 2 examine knowledge of the causes and sequelae of concussion through 18 true/false items. In Section 1, knowledge was examined using 15 items (e.g., "*After 10 days, symptoms of a concussion are usually gone*").

In Section 2, knowledge was assessed by using three scenario-based, applied items (e.g., "*Player Q and Player X collide. Player Q has never had a concussion in the past. It is likely that Player Q's concussion will affect his long-term health and well-being*".) Section 5 contained a checklist of eight commonly reported post-concussion symptoms (e.g., headache) and eight distractor symptoms (e.g., hives). Standard RoCKAS scoring assigns one point for correctly answered items on sections 1 and 2 and the true symptom items from section 5, with incorrectly answered items receiving no points. The sum of these responses yields a score for the Concussion Knowledge Index (CKI). CKI scores range from 0-25, with higher scores indicated stronger levels of concussion knowledge.

Three other items from Section 1 make up the Validity Scale (VS). The VS items assess "poor/inconsistent effort" and/or lack of thoughtfulness when completing the survey (Rosenbaum & Arnett, 2010). The wording of two of these VS items was modified for use in this study. The modification followed recommendations for alteration of items on this measure (Kinmond et al., in press). The item, "*Cleats help athletes' feet grip the playing surface*" was revised to "*Cleats (also known as sprigs, tags, studs and stops) are used to help athletes' feet grip the playing surface*". The item, "*High-school freshmen and college* *freshmen tend to be the same age*” from the original survey was replaced with, “*The colour of a player’s rugby shirt has an effect on whether the team wins*”. Possible scores on the VS range from 0-3. A cut-off score of < 2 indicates invalid responses (Rosenbaum & Arnett, 2010).

Concussion Attitudes

Concussion Attitudes were assessed via the 15 items from Sections 3 and 4 of the RoCKAS. Each item was assessed on a 5-point Likert scale ranging from “*strongly disagree*” to “*strongly agree*”. The CAI items can be categorised into 10 items assessing personal attitudes and 5 items assessing perceived norms of athletes’ attitudes (Kroshus, Daneshvar, et al., 2014; van Vuuren et al., 2020) Five of the 15 items assessed perceived norms such as, “*I feel that coaches need to be extremely cautious when determining whether an athlete should return to play*” and the remaining 10 items utilised scenarios as previously described to assess personal attitudes towards concussion. Item scores were totalled to compute the Concussion Attitudes Index (CAI). Scores ranged from 15-25, with higher scores representing “safer” attitudes about concussion (Rosenbaum & Arnett, 2010, p. 4)

Rehabilitation Recommendations After Concussion

One question assessed awareness of common options for recovery from PPCS. The item asked participants to provide an open-text response to the item “*List three recommendations for recovery after a concussion*”. The responses were then independently coded by two researchers for inter-rater consistency. Responses that were aligned to medical and current concussion management guidelines were given 1 point (e.g., rest for 24-48 hours, no exertion) and those that were not aligned were given 0 points (e.g., drink water, stay in a dark room). There was discordance in the researcher’s coding in 10% of the responses and an agreement was reached after a discussion. A third researcher acted as a mediator when an agreement could not be reached. This process allowed quantification of the open-ended responses to obtain a recommendation score (i.e., *RehabRec*) ranging from 0 to 3, with higher scores indicating more informed recommendations for PPCS rehabilitation.

4.3.3 Procedure

All questions were developed on the Qualtrics survey platform (Qualtrics, 2005), and a link sent out to participants through email and advertising on brochures and social media (see Appendix E for the complete survey). Consent was sought at the start of the survey before participants could proceed. Participants who were first-year undergraduate students were awarded course credit for participation. All other participants were not given any incentives. The survey was active from March to May 2020. The order of sections within the questionnaire was as follows: demographics, history of injury, sports participation, prior concussion education, advice for recovery after a concussion, and the RoCKAS. The survey took approximately 40 minutes to complete.

4.3.4 Analysis

The completed responses from the survey were exported from Qualtrics to IBM Statistical Package for the Social Science (SPPS) version 27. To explore sub-group differences in CKI, CAI and *RehabRec* scores, independent *t*-tests were used. Following tests for homogeneity of variance (i.e., Levene's test), independent *t*-tests compared the CKI, CAI and *RehabRec* scores between gender, those who played/did not play` contact sports, had/did not have prior concussion education, and had/did not have a prior concussion history. Cohen's *d* was computed and reported as the effect size for significant differences. Pearson's *r* correlations were used to measure the degree of association between CKI, CAI and *RehabRec* scores. Unless otherwise stated, a *p* level of 0.05 determined statistical significance. As per precedent (Kroshus, Baugh, et al., 2014; Kroshus, Daneshvar, et al., 2014; van Vuuren et al., 2020), total and item level RoCKAS scores were examined, and percent correct for each item was reported. Misconception was defined as any item answered correctly by < 50% of the sample.

4.4 Results

4.4.1 Descriptive Analysis

Table 4.1 shows the descriptive statistics for the overall sample and the subgroups. Overall CKI scores in the study ranged from 10-24, with a mean score of 19.30 (*SD* = 2.05) out of a possible 25. On average, participants correctly answered 77.2% of the CKI questions. Overall CAI scores ranged from 40 to 75, with a mean score of 61.82 (*SD* = 6.74) out of a possible 75. On average, participant correctly responded to 82.3% of CAI questions. Overall, the mean *RehabRec* score was 1.67 (*SD* = .85) out of a possible 3.

Most of the participants did not report a prior concussion (77%), did not participate in contact sport (79%), and did not report receiving prior concussion education (75%). Looking across the subgroups, the lowest average CKI score was obtained by the group with a history of concussion, whereas the highest CKI scores was in the group with prior education on concussion. Those who played contact sports had the lowest average CAI score while the highest average CAI score was in the group who did not play contact sports. The lowest mean *RehabRec* scores was from the group with a concussion history while the highest *RehabRec* score was in those without a concussion history.

4.4.2 Score Comparisons Between Subgroups

Mean comparisons were carried out between the subgroups using independent *t*-tests. There were no significant differences between the mean CKI scores for any of the sub-group comparisons. On average, participants who did not play contact sports (M=62.45, SD = 6.30) scored significantly higher on the CAI than those who played contact sports (M=59.47, SD = 7.81), $t(222) = 2.94$, p=.007; $d = 0.42$ (medium effect). Those without a concussion history had a significantly higher average CAI score (M=62.34, SD = 6.06) than those with a previous injury (*M*=60.02, *SD* = 6.99), $t(222) = 2.16$, $p = .03$; $d = 0.35$ (medium effect). All other mean comparisons of the CAI scores by subgroups were non-significant.

Table 4. 1

Mean Scores and Standard Deviations on the CKI, CAI and RehabRec Scores by Subgroup and for the Overall Sample

		Mean (*SD*)		
Demographic	N	CKI (0-25)	CAI (15-75)	RehabRec (0-3)
Total Sample	224	19.30 (2.05)	61.82 (6.74)	1.67 (0.85)
Gender				
Male	50	18.98 (2.43)	60.2 (7.77)	1.72 (0.76)
Female	174	19.36 (1.93)	62.29 (6.36)	1.66 (0.87)
Age				
18-24 years	186	19.15 (2.12)	61.89 (6.87)	1.66 (0.85)
25-30 years	22	19.90 (0.87)	61.45 (5.59)	1.64 (0.85)
> 30 years	16	19.81 (2.23)	61.56 (6.96)	1.88 (0.81)
Education				
At least high school	3	19.67 (1.53)	62.00 (5.00)	1.33 (0.58)
Completed high school	150	19.21 (1.93)	61.99 (6.89)	1.69 (0.85)
Trade/technical/vocation training	38	19.32 (2.41)	60.61 (6.61)	1.58 (0.76)
Bachelor’s Degree	32	19.50 (2.29)	62.59 (6.43)	1.75 (0.95)
Postgraduate Degree	1	19.00 (-)	57.00 (-)	1.00 (-)

Play contact sports				
Yes	47	18.83 (2.64)	59.47 (7.81)	1.60 (.92)
No	177	19.39 (1.86)	62.45* (6.30)	1.69 (0.83)
Prior concussion education				
Yes	55	19.51 (2.18)	62.20 (6.42)	1.64 (0.82)
No	169	19.20 (2.01)	61.70 (6.85)	1.69 (0.85)
Concussion Hx				
Yes	52	18.82 (2.14)	60.02 (6.99)	1.54 (0.81)
No	174	19.40 (2.02)	62.34* (6.60)	1.71 (0.85)

Note. N = 224. CKI =Concussion Knowledge Index; CAI = Concussion Attitude Index; RehabRec = Rehabilitation Recommendation Score

* $p = <.05$

4.4.3 Item-level Analysis

Tables 4.2 and 4.3 show the percentage of correct responses for each of the CKI items. Less than half of the participants responded correctly to the items highlighted in bold. Most participants could correctly identify that loss of consciousness was not necessary for a concussion (98%), symptoms after a concussion could persist (96%) and the risks of second-impact syndrome (91%). A little more than half correctly responded to items on concussions occurring without a direct head impact (62%) and post-concussion symptoms usually not lasting more than 10 days (57%). Less than half the participants (43%) were not able to correctly identify increased risks of subsequent concussions after a first injury. A much lower percentage (23%) of participants did not correctly identify that post-concussion symptoms could extend beyond memory and recognition problems. The lowest percentage of correct responses were for the item that required identifying loss of consciousness after a concussion as a coma (18%) and the item on effectiveness of neuroimaging in identifying physical brain damage after a concussion (14%).

Table 4. 2

Correct Responses on the CKI Items

CKI Item	Correct responses (%)
There is a possible risk of death if a second concussion occurs before the first one has healed. (T)	91
People who have had one concussion are more likely to have another concussion. (T)	**43**
In order to be diagnosed with a concussion, you have to be knocked out. (F)	98
A concussion can only occur if there is a direct hit to the head. (F)	62
Being knocked unconscious always causes permanent damage to the brain. (F)	81
Symptoms of a concussion can last for several weeks. (T)	96
Sometimes a second concussion can help a person remember things that were forgotten after the first concussion. (F)	77
After a concussion occurs, brain imaging (e.g., CAT Scan, MRI, X-Ray, etc.) typically shows visible physical damage (e.g., bruise, blood clot) to the brain. (F)	**14**
If you receive one concussion and you have never had a concussion before, you will become less intelligent. (F)	98
After 10 days, symptoms of a concussion are usually completely gone. (T)	57
After a concussion, people can forget who they are and not recognize others but be perfect in every other way. (F)	**23**

Concussions can sometimes lead to emotional disruptions. (T)	97
An athlete who gets knocked out after getting a concussion is experiencing a coma. (T)	**18**
There is rarely a risk to long-term health and well-being from multiple concussions. (F)	88
It is likely that Player Q's concussion will affect his long-term health and well-being. (F)	77
It is likely that Player X's concussion will affect his long-term health and well-being. (T)	90
Even though Player F is still experiencing the effects of the concussion, her performance will be the same as it would be had she not suffered a concussion. (F)	93

Note. N = 224. CKI = Concussion Knowledge Index. Items that less than half the participants answered correctly identified in bold. These items were answered true (T) or false (F). The correct responses are denoted in parentheses after each item.

Specific to symptom recognition, participants were able to correctly distinguish most of the legitimate items from the distractor items. However, there was still some uncertainty noted in correctly identifying symptoms such as panic attacks (79%) and reduced breathing (54%) as distractor symptoms. Most participants could not correctly distinguish difficulty speaking as a distractor symptom with only 19% of participants being able to correctly identify this.

Table 4. 3

Responses on Concussion Symptom Checklist (Section 5) of CKI

Symptoms (Distractor/Legitimate)	Correct responses (%)
Hives (D)	99
Headache (L)	98
Difficulty Speaking (D)	**19**
Arthritis (D)	99
Sensitivity to Light (L)	91
Difficulty Remembering (L)	94
Panic Attacks (D)	79
Drowsiness (L)	86
Feeling in a “Fog” (L)	81
Weight Gain (D)	99
Feeling Slowed Down (L)	84
Reduced Breathing Rate (D)	54
Excessive Studying (D)	99
Difficulty Concentrating (L)	95
Dizziness (L)	98
Hair Loss (D)	100

Note. N = 224. CKI=Concussion Knowledge Index; D=Distractor items, L=Legitimate items. Items that less than half the participants identified correctly are shown in bold.

Table 4.4 shows the percentage of responses representing safer attitudes on the CAI items based on scoring recommendations by Rosenbaum and Arnett (2010). As more than 50% of participants responded correctly to all the items, the items in bold reflect the 3 items with the lowest percentage of responses indicating safer attitudes. The 5 items assessing perceived norms of athletes' attitudes are shown in italics. Participants scored much lower on these items on perceived norms (i.e., less safer attitudes) than on items about their personal attitudes. The items with the lowest proportion of responses indicating safer attitudes were on personal attitudes about athletic trainer making a return to play (RTP) decision (56.1%), athlete's perception about RTP for a crucial match (54.8%), and athlete's perception that the athletic trainer should make decisions about RTP (42.5%).

Table 4. 4

Percentage of Responses Indicating Safer Responses in the CAI

CAI Item	Safer attitudes (%)
I would continue playing a sport while also having a headache that result from a minor concussion. (R)	78
I feel that coaches need to be extremely cautious when determining whether an athlete should return to play.	94
I feel that concussions are less important than other injuries (R)	88
I feel that an athlete has a responsibility to return to a game even if it means playing while still experiencing symptoms of a concussion. (R)	96
I feel that an athlete who is knocked unconscious should be taken to the emergency room.	93
I feel that Coach A made the right decision to keep Player R out of the game.	95
Most athletes would feel that Coach A made the right decision to keep player R out of the game.	63

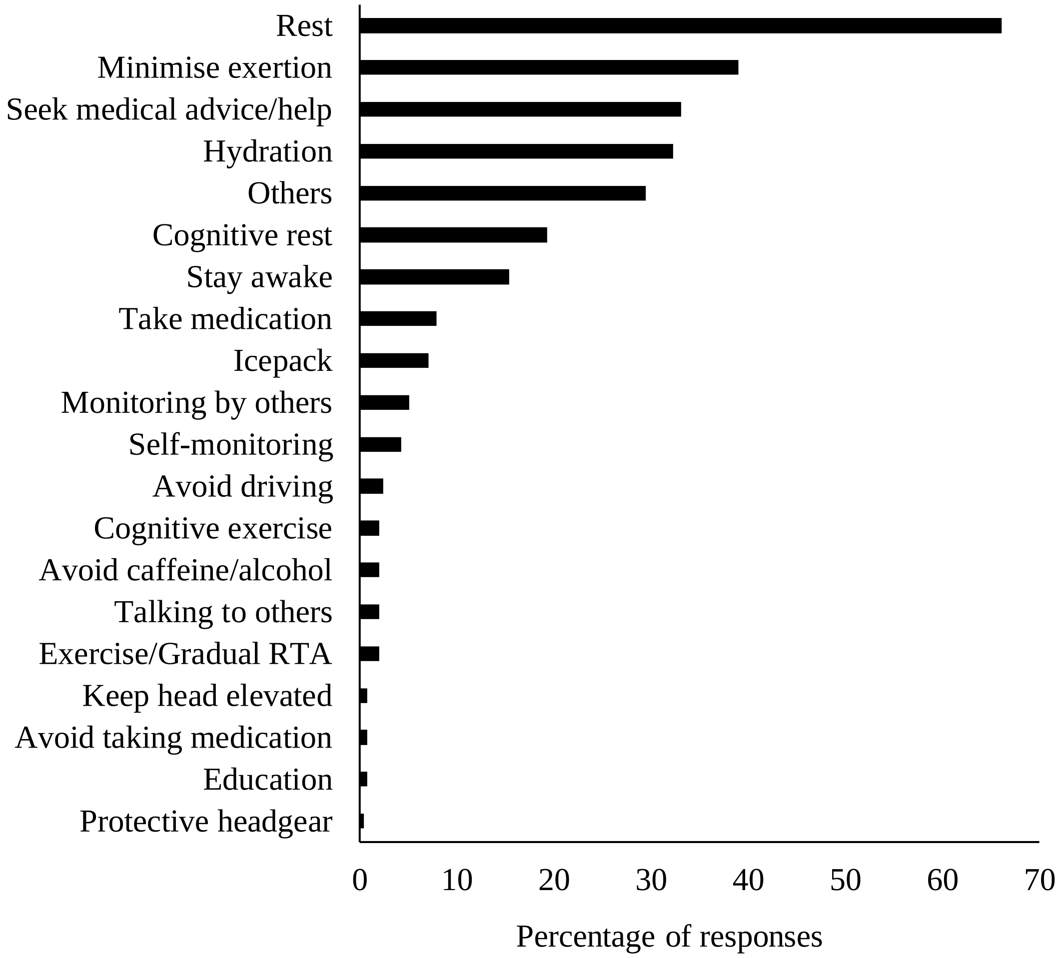
I feel that Athlete M should have returned to play during the first game of the season. (R)	93
Most athletes would feel that Athlete M should have returned to play during the first game of the season. (R)	65
I feel that Athlete O should have returned to play during the semi-final playoff game. (R)	91
Most athletes feel that Athlete O should have returned to play during the semi-final playoff game. (R)	**54.8**
I feel that the athletic trainer, rather than Athlete R, should make the decision about returning to play.	**56.1**
Most athletes would feel that the athletic trainer, rather than Athlete R, should make the decision about returning Athlete R to play.	**42.5**
I feel that Athlete H should tell his coach about his symptoms.	93
Most athletes would feel that Athlete H should tell his coach about the symptoms.	64

Note. N = 224. Reverse coded items are denoted with an R in parentheses. Items with the lowest percentage of safer responses are shown in bold. Items assessing perceived norms are in italics.

Figure 4.1 shows the coded category of responses to the *RehabRec* question asking for recommendations for recovery after a concussion. More than 70% of the responses suggested rest while only a third of the responses (33%) included seeking further medical help. Psychological approaches such as seeking social support/help from others or engaging in mentally stimulating activities were only mentioned in a small percentage of responses (< 5%). Recommendations to exercise or following RTP guidelines were suggested by approximately 2% of overall responses.

Figure 4. 1

Recommendations for Recovery based on Coded Response Categories



4.4.4 Correlation Between CKI, CAI and RehabRec

Table 4.5 shows the correlation matrix for the CKI, CAI and *RehabRec* scores. There was a significant positive relationship observed between CKI and CAI scores, but the relationship was weak. While a weak, positive relationship was observed between CAI and recommendation scores, this was not significant. There was no significant relationship between CKI scores and *RehabRec* scores.

Table 4. 5

Correlation Matrix for the CKI, CAI and RehabRec Scores

Measure	1	2	3
1. CKI	-		
2. CAI	.18*	-	
3. RehabRec	-0.01	0.11	-

Note. N = 224. CKI= Concussion Knowledge Index; CAI=Concussion Attitude Index; RehabRec=Recommendations for Rehabilitation Score

*p<.001

4.5 Discussion

This study aimed to investigate the current state of knowledge and attitudes about concussion and rehabilitation in an Australian community sample. The first hypothesis (**H3**) that participants who played contact sports would report higher levels of concussion knowledge was not supported. The second hypothesis (**H4**) that participants who played contact sports would demonstrate safer attitudes towards concussion was not supported; however, the inverse was true, where those who did not play contact sports had significantly safer attitudes than those who did play such sports. The third and fourth hypotheses (**H5**, **H6**) that people who had prior concussion education would demonstrate higher levels of knowledge and safer attitudes were both not supported. The fifth hypothesis (**H7**) that prior concussion history would lead to higher levels of knowledge was not supported. While the sixth hypothesis (**H8**) that a history of concussion would result in safer attitudes towards concussion was not supported, inverse findings were observed; those without a history of concussion reported safer attitudes.

To explore the extent of knowledge regarding rehabilitation (**H9**), an exploratory question on common recommendations for rehabilitation was used. In this sample, rest and minimising exertion were the most common recommendations, with only 2% of the participants indicated exercise or gradual resumption of activity.

4.5.1 Concussion Knowledge

Overall, the CKI scores in this Australian community sample were lower than findings from Kroshus et al. (2015), comparable with several studies (Chinn & Porter, 2016; Kraak et al., 2018; Lystad & Strotmeyer, 2018) and higher than others (Gallagher & Falvey, 2017; Gouttebarge et al., 2019; Williams et al., 2016). Such higher knowledge levels in the community were also observed by a previous study by Sullivan et al. (2020) on predictors of concussion knowledge. Considering that almost all the comparison studies were conducted in males and among athletic populations who may be better exposed to education initiatives, the sample profile in this study who were predominantly females, did not play contact sports, and did not have prior concussion education performed better than expected. A possible inference is that current community awareness about concussions is reaching out in a similar manner as initiatives among athletic communities in this sample.

Despite the high knowledge scores, the survey findings indicated that people were still not familiar with the risks of repeated injuries, correctly identifying that the loss of consciousness after a concussion is a coma and understanding that physical brain damage arising from concussions cannot be typically detected through brain imaging techniques. Similar findings suggesting a knowledge gap in these areas have been reported elsewhere (Kraak et al., 2018; Olutende et al., 2019; Viljoen et al., 2017; Williams et al., 2016). A considerable proportion of participants in this study was also unable to correctly recognise that concussion symptoms extended beyond just memory issues. These can have potential implications in understanding the complexity of PPCS where symptoms can affect individuals across domains as well as being aware of when to seek help and consider appropriate management strategies.

The sub-group analysis revealed that concussion knowledge was not impacted by a history of concussion, sports participation, or prior concussion education. While it was expected that these factors would contribute towards greater concussion knowledge, this was not supported in this sample. Although Cusimano et al. (2017) reported that a history of concussion led to higher levels of concussion knowledge in a measure similar to the RoCKAS, similar knowledge gaps, as identified in this study, were prevalent among those with a previous injury. Other studies in athletes were more aligned to findings from this study where a history of injury did not contribute towards better knowledge (Beran & Scafide, 2022; Gallagher & Falvey, 2017; Salmon et al., 2020), but it is noteworthy that despite experiencing an injury, knowledge gaps were still prevalent in such high-risk sports settings. Comparing player and parent knowledge, Hecimovich et al. (2016) found prior education in concussions led to better knowledge among only parents but both history of injury and prior education did not have any significant impact on players' knowledge.

The findings from current literature and this study converge that concussion education must be improved. While the empirical support around this is drawn mostly from studies on sports communities, it is far more concerning that having prior exposure to education resources, having a prior concussion or participation in contact sports did not significantly improve concussion knowledge. It is therefore argued that education efforts for the general community and athletes need to address some of the important gaps in concussion knowledge (e.g., symptoms can persist in various domains)

4.5.2 Concussion Attitudes

The overall CAI scores in this community sample were better than those reported in other studies on athletes (Chinn & Porter, 2016; Gouttebarge et al., 2019; Manasse-Cohick & Shapley, 2013; van Vuuren et al., 2020). It is difficult to attribute changes or improvements in attitudes to education efforts or knowledge improvement as several studies have reported education to not effectively change attitudes (Caron et al., 2018; Manasse-Cohick & Shapley, 2013). One interpretation, given that most of the participants in this sample did not engage in contact sports, is that the better CAI scores could be attributed to this sample being generally risk averse. It is also possible that as with concussion knowledge, this sample is more informed about the consequences of not reporting concussions and the potential consequences.

An important finding that warrants closer examination is the “less safe” responses when it came to perceived attitudes of athletes. The responses suggest that while participants themselves would adopt safer attitudes regarding RTP after a concussion, they had an impression on a much riskier culture among sportspeople. Considering the way in which such injuries in a sports context are portrayed or talked about in the media, this finding is not surprising (Ahmed & Hall, 2017; Kollia et al., 2018). Schlosser (2016) found riskier attitudes towards concussion to be associated with a higher expectation of masculine attributes such as toughness and restrictive emotionality in contact sports. Commentary and other media language about concussions in sports have been shown in previous studies to influence people’s perception of injury and attitudes regarding RTP (Kennard et al., 2018; Ku et al., 2020; McLellan & McKinlay, 2011). In this context, it is possible that people may be assuming that a sense of false impunity or pressure to continue playing in the interest of winning prevails among athletes.

Another section in the CAI where less safer attitudes were recorded in this study centres around the idea of an athletic trainer making decisions about RTP. Just over half of the participants felt that the athletic trainer should make the decision about RTP after a concussion and less than half thought that other athletes would feel the same way about deferring the decision to the athletic training. While the intent behind these questions lies with according a key responsibility to a trained authority within the team, the participants in this study could be expecting athletes to be responsible for their own injuries instead of relying on a trainer's assessment. This finding highlights a glaring problem that may require further addressing. Participants in this study may feel that it is safer and more responsible for athletes to make their own decisions about RTP but unfortunately, underreporting has been highlighted as a major issue among athletes (Craig et al., 2019; Kerr et al., 2014; Kroshus et al. 2014; Kroshus et al., 2015; Register-Mihalik et al., 2013). If left to their own devices, athletes may pose themselves considerable risks due to reinjury or in the worst case, fatal consequences. Such issues need to be addressed in greater detail for participants who may be playing sports or may be parents of athletes.

The sub-group analysis among CAI responses found significant differences in scores between those with a history of concussion versus those without a history, and those who played contact sports versus those who did not. Contrary to expectations, those who did not have a prior injury or participate in sports reported safer attitudes. Register-Mihalik et al. (2017) presented a similar finding where having a previous concussion did not lead to differences in attitudes towards concussion. A possible reason for such findings could be attributed to those who have had a prior injury and did not experience significant or debilitating symptoms. This could have resulted in such individuals being less likely to consider such injuries to be serious enough to warrant reporting, resulting in riskier attitudes. For those who did not participate in sports, adoption of safer attitudes could plausibly be due to being generally risk-averse, and not having been exposed to team cultures or peer influences that encourage risk-taking and underreporting behaviours.

4.5.3 Rehabilitation Recommendations

It is encouraging that most of the recommendations for rehabilitation in this study were centred around rest or minimising exertion. This is somewhat aligned to the current management guidelines (Elkington et al., 2019; McCrory et al., 2017), but it is not possible to infer if participants were alluding to an initial phase of rest for 24-48 hrs or prolonged rest till asymptomatic that has shown to be less effective. An accurate understanding that gradual activity can resume after an initial phase of rest does not seem likely among most participants based on their responses to the *RehabRec* question. Only a small proportion who suggested exercise mentioned terms like "*gradual activity after 48 hours*" and "*rest for 24-48 hours before resuming physical activity*". Several responses were also akin to common misconceptions (e.g., staying in a dark room, staying awake) that may require addressing through future education. Specific to this study, only a very low proportion of participants acknowledged exercise or gradual resumption of physical activity in some form as an option to consider for rehabilitation after a concussion.

4.5.4 Relationship Between Knowledge, Attitude and Rehabilitation Recommendation

Previous studies using similar measures of knowledge and attitude have found little or no association between these scores (Anderson et al., 2016; Gallagher & Falvey, 2017; Kraak et al., 2018). In this study, knowledge scores were significantly associated with safer attitudes, but the strength of the relationship was weak. It is possible to interpret this in a positive light to suggest that those with higher knowledge in this sample also demonstrated reasonably safer attitudes. However, the lack of a strong relationship also highlights that having good knowledge may not always translate to safer attitudes towards concussion. A recent systematic review by Beran and Scafide (2022) found several individual and institutional factors contributing to the lack of relationship between knowledge and attitudes. Consistent with previous recommendations (Rivara et al., 2014), this study concurs that shaping safer attitudes goes beyond improving knowledge in individuals and highlights the need to consider more concerted initiatives targeting influential factors such as sports coaches, schools, media, and healthcare professionals.

A novel aspect of this study was to introduce a measure of awareness of current post-concussion rehabilitation. The lack of relationship between knowledge, attitudes and rehabilitation advice supports a key argument in this study. People may obtain general knowledge and adopt safer attitudes about concussion based on media coverage and existing education programs but information on current rehabilitation guidelines may be found wanting. The most common response to rest or minimise exertion can be regarded as a recommendation assumed to be logical after an injury and possibly due to a strong influence of conservative medical approaches. Therefore, efforts to bring information about evidence-based rehabilitation possibilities such as exercising to the community is necessary once the effectiveness of exercise rehabilitation in wider populations are better established.

4.5.5 Implications of Findings

Taken together, the study findings suggests that general knowledge and attitudes were higher than average in this Australian community sample. However, common gaps relating to identification of injury, persistent symptom onset and rehabilitation are present. Previous findings have reported gender differences in knowledge and attitudes, with females reporting significantly higher knowledge scores and reporting behaviours (Mayashita et al., 2016; Wallace et al., 2017), but there were no significant differences between gender knowledge, attitudes, and recommendations for rehabilitation in this study. For those with a history of injury or actively participating in contact sports, seriousness of reinjuries and the possibility of persistent symptoms that can lead to functional impairment and rehabilitation options are important information critical to managing concussion and PPCS. Not knowing about best practices can suggest adoption of ineffective practices that do not aid recovery or lead to more significant impairments. Current initiatives to educate athletes do not appear to be effectively targeting such issues.

Drawing from such findings, education programs for concussion can be more comprehensive by identifying and pay more attention to such misconceptions or lack of awareness. Initial programs can be administered in sports communities given their higher susceptibility to risks but these programs should also be extended to the general community given similar gaps in knowledge and risks faced through non-sports related concussions. More specific information on concussion management and rehabilitation can also be offered as discharge advice for people who have suffered a concussion as they could be more susceptible to greater risks. To help shape safer attitudes towards reporting concussions, individual education efforts alone will not suffice, and it is important to create a culture that is more supportive of concussion reporting and active help seeking for rehabilitation.

Perceptions about riskier attitudes in athletic communities can permeate to wider society and encourage trivialising of injuries in various contexts. If people think that sports participation entails a "tough" attitude to continue playing despite injuries or underreport injuries for the interests of the team, they could adopt similar attitudes when they play these sports themselves or in their roles as coaches and parents of athletes. Transparent communication about initiatives to inculcate return to play guidelines in sports can be established with the public as part of improving perceptions about sports culture. A clear example of this is seen in the recent release of a concussion management protocol by the Ultimate Fighting Championship (UFC) Performance Institute for Mixed Martial Arts (UFC Performance Institute, 2021). For a sport that is notorious for concussions, identifying management efforts that are aligned to other contact sports is a good starting point to highlight risks and provide advice on injury management to the public.

Efforts to dispel a widely held view about prolonged rest may not be easy but is important for faster recovery and return to functioning. This is not to say that participants knew about the benefits of such exercise rehabilitation or gradual resumption of activities in the first place and more efforts are required to make such research findings easily accessible to the public. Education resources that include terms such as “rest for 24-48hrs”, “sub-symptom threshold activity”, “symptom-limited exercise” or “individualised programs” can be useful to promulgate the idea that while the general advice is to rest until asymptomatic, partaking in activity-based approaches for recovery after a short period of rest has shown promise in empirical studies. Normalising such terms can shift traditional perspectives of prolonged rest after such injuries and help the community to be more receptive towards active rehabilitation.

4.5.6 Future Directions

Future education efforts can explore more effective knowledge translation strategies with the integration of the discussed implications. The lack of association between knowledge and attitudes in this study further supports the notion that driving changes in attitude cannot be achieved through merely improving knowledge (Anderson et al., 2016). Efforts to improve both are recommended through programs that do not just target individuals but also attempt to shift institutional culture (Beran & Scafide, 2022; Register-Mihalik et al., 2013). Further, there is also a need to include education on evidence-based rehabilitation. As recommended by Provvidenza et al. (2013), incorporating context-specific information that is guided by theory-driven knowledge, and harnessing wider platforms such as social media for regular, and greater outreach can be key for longer term knowledge retention and attitude change.

4.5.7 Strengths

A strength of this study was to explore the current state of knowledge and attitudes about concussion in an Australian community sample. Unlike most other studies that focused on the sports community, this study extended this area of research to the general community with the intent of identifying gaps in knowledge translation between empirical evidence and current practices.

This was the first study to include a measure of rehabilitation knowledge. By examining recommendations for recovery after a concussion, it was possible to infer that people tend to adopt more conservative approaches after a concussion. This finding can be useful to shape future programs that can help to alter misconceptions with the support from empirical literature. In turn, this could increase uptake of exercise or other rehabilitation options that are shown to be effective. The findings from this study suggest that the community may need more guidance about what they can do to manage symptoms after a concussion.

4.5.8 Limitations

There are several limitations in this study. First, this study aimed to assess knowledge and attitudes in an Australian community sample, but there were constraints on the sampling methods that could be used. Ideally, for this aim to be achieved, a stratified sampling approach would be used to attain a representation sample. However, resource constraints precluded this method, therefore a convenience method was used. The resulting sample comprised mostly young females and was imbalanced with regard to most participants not having a history of concussion, not playing contact sports, and not having prior concussion education. Unlike most concussion studies that have been carried out on primarily male populations, the predominantly female sample could be possibly due to the make up of students from the university participation pool. Therefore, the sample is not representative of the Australian community.

Second, the RoCKAS is a survey on concussion knowledge and attitudes that was developed in 2010 and specifically for athletic communities. Some of the items may require updating for relevance to the general community in future studies. For example, it is difficult to attribute incorrect responses on items such as "*An athlete who gets knocked out after getting a concussion is experiencing a coma"* and "*After 10 days, symptoms of a concussion are usually completely gone"* to a lack of knowledge among this sample. It can be difficult for the general community to understand terms like "coma" being applicable to a concussion where consciousness is regained in a few minutes. Similarly, current consensus guidelines suggest that abnormal recovery from a concussion is >14 days for adults and >28 days for adolescents while the RoCKAS item only describes a cut-off of 10 days for symptom persistence. Taking into further consideration the ambiguity observed in such time frames reported in empirical studies, it is not possible to interpret an incorrect response on this item by a member of the community as a lack of knowledge.

Third, the phrasing of the question to assess *RehabRec* (e.g., *List three things you would recommend to someone who has suffered a concussion to help with their recovery process*) could have had a conservative nuance that primed participants to offer suggestions that are more recuperative. The open-ended nature of the question and subjectivity in participant's perceptions suggests that findings should be interpreted with caution. The development of a validated measure to assess knowledge on rehabilitation and provide a more objective score can be a useful consideration for future studies.

4.6 Conclusion

This study was the first to explore concussion knowledge, attitudes, and rehabilitation recommendations in an Australian community sample. In addressing a central question in this thesis regarding the current state of knowledge in the community, it was found that knowledge gaps on concussion symptoms and risks are still prevalent. Community perception of a risk-taking culture towards concussions within athletic communities was also identified. The gaps in knowledge translation between rehabilitation research and practice was evident in this community where recommendations appeared to centre around traditional approaches such as rest. The prevailing knowledge gaps identified in this study and a hesitance to identify exercise as a potential rehabilitation option supports the need for more targeted education that addresses not just identification of concussion symptoms and general attitudes but also evidence-based rehabilitation. Future education efforts should focus on current knowledge gaps, correcting misconceptions about sports cultures and theory-driven rehabilitation.

4.7 Chapter Summary

This chapter aimed to explore the current state of knowledge and attitudes about concussion and rehabilitation in an Australian community sample. The findings revealed that while this sample reported higher knowledge and safer attitudes towards concussion, there were still common knowledge gaps and misconceptions that were identified. More importantly, only 2% of the sample referred to physical activity or alluded to some form of exercising as a rehabilitation option. The findings support a key argument in this thesis that one of the reasons for a lack of adoption of PPCS rehabilitation is due to lack of knowledge about such options. These findings will be useful to develop targeted education efforts that address knowledge gaps and highlight the effectiveness of exercise rehabilitation when such approaches are ready for implementation in the wider community. The next chapter will explore further knowledge translation gaps such as personal sociocognitive constructs that may influence the decision to participate in PPCS exercise rehabilitation.

Chapter 5: The Sociocognitive Determinants Underlying Intentions to Exercise after a Concussion

5.1 Chapter Introduction

The third and final study in this thesis aimed to (1) investigate the determinants of *intention* to exercise after a concussion, (2) explore desirable features of an ideal exercise rehabilitation program for PPCS, and (3) identify potential barriers to exercise participation after a concussion. This information was sought to contribute towards the missing pieces of the puzzle in the current knowledge translation gaps specific to PPCS rehabilitation. Study 1 identified useful exercise parameters for further exploration and possibly wider adoption in the community. Study 2 showed that knowledge about the effectiveness of exercise to aid recovery from concussion is not top of mind for most people; it was not identified as the top three options when study participants were asked about recommendations for recovery. While these gaps could be addressed through education efforts, improving knowledge alone has shown to be ineffective for wider attitudinal or behavioural change (Anderson et al., 2016; Black et al., 2020; Glang et al., 2015). There could be further situational and environmental factors at play and exploring these factors may be necessary to better understand the reasons behind decisions people make specifically towards post-concussion rehabilitation. By using an extended theory of planned behaviour, this study examined the underlying factors that could contribute towards participating in an exercise rehabilitation program after a concussion. As recommended in intervention design literature (Bowen et al., 2009, El-Kotob et al., 2018), a secondary aim was to identify factors that could increase the feasibility and potential barriers to exercise participation. These factors are expected to contribute towards planning and development of future post-concussion exercise interventions.

5.2 The Theory of Planned Behaviour

The theory of planned behaviour (TPB) is an influential and frequently cited model to understand important sociocognitive factors that influence a particular behaviour. The TPB is an extension of the theory of reasoned action (TRA) with the addition of *perceived behavioural control* (PBC). Similar to self-efficacy and control, PBC is expected to both directly and indirectly influence *intention* and behaviour (Ajzen & Fishbein, 1980; Fishbein & Ajzen, 1975), specifically in situations where an individual has limited volitional control (Ajzen, 1985; Armitage & Conner, 2001). The TPB is commonly used to predict *intention* to perform a behaviour from a socio-cognitive perspective using measures of *attitude, subjective norms,* and *perceived behavioural control*. This widely cited model has contributed to several behaviour change interventions (Ajzen, 2019; Sommer, 2011; Tornikoski & Maalaoui, 2019). Ajzen (2019, 2020) explains that the constructs of the theory, if assessed accurately, account for a range of background factors (e.g., age, ethnicity, socio-economic status, media exposure) and that the model can predict behaviour reliably. As TPB constructs are modifiable, a better understanding of these constructs that predict a specific behaviour can be useful to design and develop evidence-based interventions for health promotion and risk reduction (Andrykowski et al., 2006; de Bruijn et al., 2014).

The TPB has been used in a handful of concussion studies previously with a focus on the drivers of concussion reporting. Register-Mihalik (2013) assessed the influence of psychosocial determinants on concussion reporting intentions using the TPB and found attitudes, subjective norm, and direct perceived behavioural control to be associated with concussion reporting. Similar studies on concussion reporting have used the TPB to explain concussion reporting behaviour (Kroshus et al., 2014; Sullivan et al., 2021). Murphy et al. (2017) assessed parents' perceptions on concussion risk and intentions to allow their children to participate in youth football. The authors found significant predictors such as social norms, attitudes towards sports participation, behavioural control, and perceived risk to account for over half of the variance in explaining the intention to allow football participation. More recently, Fontana et al. (2022) investigated parent-child communication regarding sports-related concussion using the TPB and found intention towards communicating with children about concussion to be determined by attitudes and subjective norms but not perceived behavioural control.

The present study is the first to apply the TPB in a novel context. This study aims to determine if TPB constructs can help build a better understanding of the drivers of concussion rehabilitation, which in turn could lead to evidence-based strategies for enhancing the design of a PPCS exercise program. Before explaining the study, it is necessary to explain why the TPB was chosen for the present research. The following sections introduce the model, and then discusses the evidence that supports it, including in applications that bear some similarities to the present study.

5.3 Direct and Indirect Constructs of the TPB

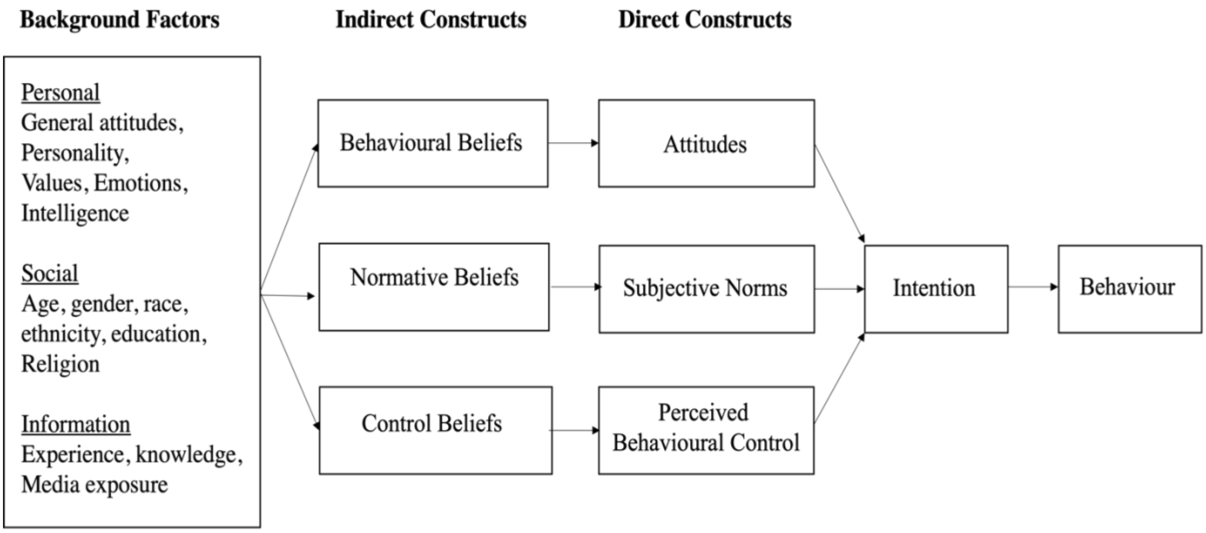
Ajzen (1985) theorised that the TPB is a belief-based theory that describe an individual's expectations and values about a target behaviour based on their *behavioural, normative* and *control beliefs*. These beliefs in turn, form people's *attitudes*, *subjective norms,* and *perceived behavioural control* towards *intention* and ultimately a behaviour (Downs & Hausenblas, 2005). While Ajzen (2019) asserts that underlying beliefs are the *formative indicators* of each of the three theoretical constructs, some TPB literature commonly refers to these beliefs as *indirect constructs* (Downs & Hausenblas, 2005) For consistency, the term "indirect constructs" will be used hereafter to describe beliefs in this paper.

Behavioural beliefs are indirect measures of *attitude*. In other words, beliefs about perceived consequences resulting from a behaviour (e.g., *exercising for 20 minutes for three times a week will be positive for my health*) and the evaluation of these consequences (e.g., *doing something positive to recover from my health is good*) make up the indirect measures of *attitude* (Ajzen & Fishbein, 1980). *Normative beliefs* are indirect measures of *subjective norms and* formulated by the perceptions of significant others regarding engagement in a behaviour (e.g., *My doctor thinks that I should exercise for 20 minutes, three times a week to improve my health*), as well as the motivation to comply with the perceptions of others (e.g., *When it comes to my health, I want to do what my doctor thinks is best for me*) (Ajzen, 1985). Finally, *control beliefs* are indirect measures of *perceived behavioural control*. This construct is developed from the evaluation of whether adoption of the behaviour will be easy (e.g., *I believe I will have the strength to exercise for 20 minutes, three times a week)* and from an assessment of perceived power over resources, skills, and opportunities (e.g., *Having the strength would enable me to exercise for 20 minutes, three times a week*) (Ajzen, 1991).

Ajzen (1985, 2019) suggests that while direct TPB constructs are adequate to predict behaviour, indirect constructs are useful to determine the antecedents driving the direct constructs. Identifying these antecedents can be useful to specify areas that require attention, and in turn facilitate behavioural change through targeted education or policies. For example, efforts targeted to alter a belief about exercise can lead to a person shifting attitudes towards exercising. Figure 5.1 illustrates the direct and indirect constructs of the TPB and the predictive pathways of these constructs.

Figure 5. 1

The Theory of Planned Behaviour



Note. Adapted from Sommer (2011)

5.4 Empirical Support for TPB

Studies reviewing the TPB have found that the three direct constructs can explain up to 40%-60% of the variance in *intention* to perform a behaviour (Armitage & Conner, 2001; Godin & Kok, 1996) with large effect sizes reported across a wide range of studies (Sutton, 1998). When compared to other behaviour prediction models, the TPB is unique for focusing on the "intention-behaviour" relationship (Hardeman et al., 2002). The importance of this relationship is further amplified when there are no readily available measures of the target behaviour (Francis et al., 2004). While the correlation between one's *intention* and participation in the behaviour (e.g., intention-behaviour gap) is not perfect, *intention* is a reliable proxy measure that indicates a strong likelihood to perform a behaviour (Ajzen, 1991). Meta-analyses on TPB studies have provided further support for reasonably strong links between *intention* and actual behaviour (Randall & Wolff, 1994; Sheeran et al., 2003). Criticisms of the TPB include the fact that some variance of *intention* is usually not fully accounted for by the constructs, (Sheeran et al., 2003; Sommer, 2011), but the theory is nonetheless a good starting point to explore sociocognitive factors behind a specific behaviour such as participation in PPCS exercise rehabilitation.

5.5 TPB and Exercise

The TPB has been applied in myriad studies exploring exercise *intention* and behaviour. In a literature review, Blue (1995) concluded that the TPB was useful to identify psychosocial determinants of self-reported exercise, leading to the design of more efficient exercise programs. A meta-analysis by Hausenblas et al. (1997) reported large effect sizes for predicting exercise based on *intention*, *attitude*, and *perceived behavioural control* but the effect size for *subjective norms* was found to be only moderate. Hagger et al.'s (2002) meta-analysis on 72 studies found the TPB to account for a significant proportion of the variance in exercise participation. The Hagger et al. meta-analysis also identified factors such as previous behaviour to mediate the relationship between TPB constructs. Downs and Hausenblas (2005) found that exercise *intention* was strongly associated with *attitudes* and *perceived behavioural control* but pointed out that the operationalisation of these constructs and other variables (e.g., age, habits, fitness) could possibly moderate the effects on exercise. Taken together, these findings suggest that *attitudes* and *perceived behavioural control* could be more useful than *subjective norms* in predicting exercise *intention,* and the possibility of other moderating factors that could influence intention. This suggests that people's beliefs about exercise and their perceptions of self-efficacy and control regarding exercise can be more predictive than the opinions of significant others. Additionally, the inclusion of other variables such as previous exercise habits can improve the predictive utility of the TPB in an exercise context. However, it must be noted that other concepts such as identity that may have a role in exercise behaviours are not considered in the TPB.

While studies on the TPB are useful to understanding people's *intention* to exercise, it is also important to evaluate if these findings can be generalised to different clinical sub-populations. The *intention* to exercise for general health benefits might be considered to entail less risks and therefore could be much easily swayed by constructs such as *subjective norms* or self-efficacy. On the other hand, it may be possible that the views of others may have less influence in clinical populations where the risks involved are higher. Early studies using the TRA among individuals with lower-limb disabilities found only *intention* to be a strong predictor of exercise, but *attitude* and *subjective norms* were poor predictors (Godin et al., 1986). Godin et al. (1991) investigated exercise participation in individuals who suffered a heart disease. The authors found *intention* to be a strong predictor of exercise participation for heart disease, but *perceived behavioural control* moderated the effects considerably. Andrykowski et al. (2006) found positive *attitudes* towards exercise to be most consistently associated with exercise *intention* but not *subjective norms*. In a study investigating exercise *intention* in brain cancer patients, Jones et al. (2007) found *attitudes* and *perceived behavioural control* to be the most important determinants of participation in exercise rehabilitation. While these findings on exercise *intention* in clinical populations appear to mirror general trends from TPB studies, —*attitudes* and *perceived behavioural control* being more predictive than *subjective norms* —the variability in findings across studies suggest that each clinical population may be unique and thus require investigation of such factors within a particular context.

Based on current findings, it appears that *subjective norms* may not be as useful in shaping *intention* to exercise; but there are some clinical studies that have found the inverse. Courneya and Friedenreich (1999) found *attitudes* and *subjective norms* to be significant determinants of exercise *intention* for breast cancer therapy. Notably, the authors reported that the beliefs underlying the direct TPB constructs among breast cancer patients were different to those of the healthy population. Hunt-Shanks et al. (2006) found that all TPB constructs made significant, unique contributions to exercise *intention* among breast-cancer patients. The fact that *subjective norms* can be just as important as other TPB constructs has also been reported in other studies with clinical populations (Blanchard et al., 2002; Courneya et al., 2001), lending support to the idea that what significant others think about a person's engagement in exercise for health reasons, and the influence of social support to be pertinent for the success of such programs in clinical populations. That said, variability in findings of TPB constructs and their predictive utility among clinical populations is not surprising. A key tenet of TPB highlights that the constructs that influence exercise *intention* varies across populations and it is important to identify the clinical population and the target behaviour in a specific manner for an accurate understanding of the factors (Ajzen, 1991; Andrykowski et al., 2006).

Given the need for a specific and targeted approach to understand exercise *intention*, it may be problematic to theorise the relationships found in other studies to a post-concussion rehabilitation context. While the TPB has been used to understand exercise *intention* in populations with various health problems, the model has never been applied in the context of rehabilitation for people with post-concussion symptoms, highlighting the lack of a precedent. To guide this research, a specific approach of identifying the target behaviour (i.e., PPCS exercise rehabilitation) and the determinants will be taken based on a review of TPB studies (Ajzen, 2020; Godin & Shephard, 1986). This is critical to understand the social and cognitive factors involved in making rehabilitation decisions after a concussion, in particular decisions about participation in exercise. These factors will be instrumental to tailor education programs and exercise rehabilitation for this group to potentially improve participation in such programs.

Study Aim

The previous chapters have established that knowledge about graded exercise as a potential option for rehabilitation after a concussion is lacking. A commonly held view is that rest should be used for concussion; but in most cases, this approach should not be continued beyond two days post injury. It is now known that complete bed rest can be counterproductive for post-concussion recovery, especially if rest is prolonged (Giza et al., 2018). However, conservative approaches of prolonged rest after a concussion have persisted despite expert advice suggesting otherwise. Therefore, it is worthwhile to explore the sociocognitive constructs underlying *intention* to exercise, as defined by the TPB, after a recent concussion. Awareness of these constructs could contribute towards the knowledge base for future education and intervention planning targeted for PPCS rehabilitation.

While the literature suggests that different factors can be included to improve the predictive utility of the TPB, past behaviour is one of the most common factors proposed to achieve this objective (Sommer, 2011). In an exercise context, past behaviour refers to prior experience of exercising regularly or having developed a habit of regular exercise (Norman et al., 2000). Past behaviour has been associated with both stronger *intention* and higher likelihood of performing the same behaviour in the future (Ajzen, 2005; Pomery et al., 2009). In this vein, including a measure of past exercise behaviour will be useful to determine if this is an important consideration in developing exercise programs for PPCS. As exercising for rehabilitative purposes must be designed for people who are both physically active and inactive prior to needing such programs, understanding such differences, if any, should lead to program design improvements.

The primary aim for this study was to apply an extended TPB model to understand the underlying determinants that predict *intention* to exercise after a concussion. The extended TPB consists of both direct and indirect constructs inherent to the model and the measure of previous exercise behaviour. A secondary aim was to examine the practical features of exercise rehabilitation programs that people believe would improve their involvement (e.g., program cost, distance of exercise facility from home). Further, since study 1 identified the properties (e.g., duration, intensity) of an exercise program for PPCS that should prove effective, a program with these properties was described to the participants to elicit their perceptions of it. Considering the lack of precedent in TPB studies in concussion rehabilitation, the literature on general exercise rehabilitation was used to develop the hypotheses for this study. This approach assumes that PPCS will lead individuals to report similar *attitudes, subjective norms,* and *perceived behavioural control* as those with other debilitating conditions in relation to their exercise *intention*. In line with prior exercise rehabilitation literature, the hypotheses for this study were that:

H10*: Positive attitudes would be associated with stronger intention to participate in exercise for PPCS.*

H11*: Higher perceived subjective norms would be associated with stronger intention to participate in exercise rehabilitation after a concussion.*

H12*: Higher perceived behavioural control would be associated with stronger intention to participate in exercise rehabilitation after a concussion.*

H13*: Past exercise behaviour would moderate the relationship between TPB constructs and intention to exercise.*

5.6 Method

5.6.1 Participants

A convenience sample of 459 participants was recruited for the study using social media advertising, the university research recruitment portal, and the distribution of a brochure (see Appendix F). The age of participants ranged 18-72 years ($M_{age} =$ 24.0, SD_{age} = 8.78, range 18-72 years; females =72.5%). Most of the participants identified as Caucasian (70.7%) and from Queensland (93.2%). The survey was implemented globally but the response from those living outside of Australia was low (5%). Participants included first year university students (51.2%), and these participants were given academic credit for their participation. All other participants were not given any incentives. The inclusion criteria were as follows (a) aged ≥ 18 years and; (b) provided a valid response. A valid response was determined by participants who responded to more than 50% of the survey questions. A total of 480 participants completed the survey and 21 ineligible participants were removed for the final analysis (i.e., ≤ 17 years, $n = 6$; failed validity check, $n = 15$).

5.6.2 Measures

Concussion History

To identify if participants had a history of concussion, the participants were asked, "*Have you ever experienced a concussion in the past?"*. If an injury was reported, the follow up questions were the number of concussions and mechanism of injury (e.g., sport, assault).

Past Exercise Behaviour

This section of the questionnaire included five questions on personal views about exercise (e.g., *Exercise is important to me*), previous exercise behaviour (e.g., *I have exercise regularly in the past 12 months (Yes/no),* frequency of exercising each week (e.g., *How often did you exercise in the past 12 months?, How long did you exercise per session?*), and the type of exercise (e.g., walking, running, gym-based exercises). Items varied between dichotomous questions (i.e., Yes/No), Likert scale (5-point) and those that required completing a checklist.

Active-Heads Exercise Rehabilitation Program

This section presented participants with a hypothetical PPCS exercise rehabilitation program called *Active-Heads*, based on recommendations for such programs (Sullivan et al., 2018). A brief definition of concussion and post-concussion symptoms was first provided. before a statement about exercise being a promising rehabilitation option after an initial period of rest. Participants were then told to assume they had suffered a concussion 7 days ago. Then, *Active-Heads* was described as a gym-based exercise program combining aerobic and resistance training. Participants were told that the exercise would be supervised, individually calibrated and progressive at a pace that suits them. The duration of the program was indicated for 3-8 weeks, depending on how quick participants recovered. The language used throughout was simplified provide clear and consistent information about PPCS and exercise rehabilitation for the lay person.

Theory of Planned Behaviour Questionnaire

The development of the TPB questionnaire for this study was guided by widely used survey construction guidelines for TPB (Ajzen, 2013; Francis et al., 2004). Questions to assess TPB direct constructs (i.e., three sub-scales), indirect constructs (i.e., three sub-scales) and *intention* resulted in seven sub-scales for the questionnaire. A 5-point Likert scale (1 = *strongly unlikely*, 5 = *strongly likely*) was used for all items.

Attitude. *Attitude* towards the *Active-Heads* program was measured using eight direct items. Four were affective items based on how the individual felt about performing the target behaviour (e.g., *If I took part in Active-Heads, I would feel better*), and four were instrumental items based on whether the behaviour would achieve something (e.g., *If I took part in Active-Heads, my symptoms would improve*). The overall *attitude* score was the mean of all items.

Subjective Norms. *Subjective norms* regarding the *Active-Heads* program were measured using four items (e.g., *Most people who are important to me would be interested in participating in Active-Heads*). These items were drawn from the concussion literature and were intended to refer to possible reference groups for those at-risk for concussions. The overall subjective norm score was the mean of all items.

Perceived Behavioural Control. *Perceived behavioural control* was measured using five items. Three items assessed self-efficacy (e.g., *I am confident that I can participate in the Active-Heads program*), and two items were on self-control (e.g., *Whether I participate in*

Active-Heads or not is entirely up to me). The overall *perceived behavioural control* score was the mean of all items.

Behavioural Beliefs. The questionnaire included five items on *behavioural beliefs* (e.g., *If I took part in Active-Heads, it would take too much of my time*) and five items on the *subjective evaluation* of the outcome (e.g., *Spending a lot of time on an exercise program that helps with my concussion recovery is desirable/undesirable*) corresponding to the behavioural beliefs. The sum of cross products for all items was the overall behavioural belief score. Higher scores reflect higher behavioural beliefs.

Normative Beliefs. Six items were used to assess normative beliefs. Three items asked about what common reference groups would think about the target behaviour (e.g., *Doctors would approve/disapprove of my participation in Active-Heads to help with my recovery*) while three corresponding items assessed the motivation to comply given the views of the reference group (e.g., *What doctors think I should do matters to me*). The sum of cross products for all items was the overall normative belief score. Higher scores reflect higher normative beliefs.

Control Beliefs. Three items were used to assess control beliefs (e.g., *I may not have the time to take part in an exercise program like Active-Heads for recovery after a concussion*) while another three assessed the perceived power of these beliefs (e.g., *I am less/more likely to make time to participate in a program like Active-Heads after a concussion*). The sum of cross product for all items was the control belief score. Higher scores reflect higher control beliefs.

Intention. Five items were used to assess *intention* to participate in *Active-Heads* after a concussion (e.g., *I intend to do Active-Heads*). The overall *intention* score was the mean score of these five items. Higher scores reflect higher *intention* to participate in the exercise program.

Exercise Feasibility and Barriers

The final section of the questionnaire asked participants to indicate desired features of a program like *Active-Heads* using eleven items (e.g., *There would be a better chance for me to participate in Active-Heads if it was home-based*.). This was followed by a section with a checklist for participants to identify a list of potential barriers to participating in such an exercise program. For participants that indicated that distance from the venue that would provide *Active-Heads*, and time spent exercising were important factors, follow-up questions were asked to determine specific preferences (e.g., would travel 5 – 10 kms for the program).

5.6.3 Procedure

All questions were developed on the Qualtrics survey platform (Qualtrics, 2005). The steps undertaken to develop the TPB survey are shown in Table 5.1. While the approach was generally in line with the guidelines for TPB questionnaire development (Francis et al., 2004), some modifications were made for the context of this study. For example, an elicitation study was not carried out as part of item development. Elicitation studies, often done using focus groups at the outset of the process, can be useful to provide researchers with current and relevant beliefs that determine the TPB constructs. However, they are not regarded as essential and TPB and exercise studies do not usually include them (Downs & Hausenblas, 2005). Instead, all items were developed based on a comprehensive literature review and adapted for this study. This was in the interest of expediency and a lack of access to a sufficiently large clinical focus group with PPCS. To minimise issues with content validity, the item design was based on post-concussion and exercise literature and items were reviewed by an expert in concussion and PCS research.

The order of sections within the questionnaire was as follows: demographics, history of injury, treatment seeking, current exercise habits, TPB questionnaire linked to the *Active-Heads* program and feasibility and barriers of exercise program (see Appendix G). Once the survey development was complete, online links were sent to local and international participants through email, text message, social media advertising and word of mouth. Data was collected for seven months between Jul 2020 and Jan 2021.

Table 5. 1

Process of TPB Questionnaire Development

Process	Specifications
1. Defining the population of interest	Young adult population
2. Define the target behaviour using the Target, Action, Context, Time (TACT) principle	**T**: People with post-concussion symptoms **A**: Participate in rehabilitative exercise **C**: Those with symptoms after a concussion **T**: Symptoms persisting after 7-10 days of typical recovery period
3. Literature review with specific research questions for each TPB construct	**Attitudes**: How existing studies on exercise measure direct/indirect attitudes towards exercising/participation in rehabilitation after a concussion? **Subjective Norms**: What are common referent groups that can potentially influence those at risk to concussions? **Perceived Behavioural Control**: What are some factors that reflect self-efficacy and beliefs about controllability of participating in exercise after a concussion or other rehabilitation? **Intention:** How existing studies determine intention for exercise in various clinical contexts?

4. Development of TPB questionnaire items	**Direct measure of attitude:** Four affective items; four instrumental items to assess attitudes towards exercising post-concussion. **Indirect measures of attitude**: Five items on behavioural beliefs; five items on outcome evaluation of these beliefs. **Direct measure of subjective norms:** Four items assessing what important others would think of exercising post-concussion. **Indirect measures of subjective norms:** Three items assessing the normative beliefs of reference groups; three items to assess the motivation to comply in the context of the reference groups. **Direct measure of perceived behavioural control:** Three items reflecting people's confidence in participating in exercise post-concussion; two items on beliefs about the level of control people have over exercising post-concussion. **Indirect measures of perceived behavioural control:** Three items assessing control beliefs and three items assessing the perceived power of these beliefs to influence the behaviour. **Intention to participate in *Active-Heads*:**

	Five items to assess their intentions to exercise in a hypothetical exercise rehabilitation program post-concussion.
5. Review of TPB questionnaire	Consulted expert researcher to check wording of items; rephrasing of items.

Note. The process outlined here was guided by Francis et al. (2004).

5.6.4 Data Analysis

Descriptive data and exploratory factor analysis (EFA) were carried out using IBM SPSS version 27. The sample was split into half using a random 50% split on SPSS for the EFA. Confirmatory factor analysis (CFA) was done on the other 50% split sample to validate the model using IBM AMOS version 26. As advised by Ajzen (2019), correlation analysis was used to determine relationships between indirect and direct constructs of the TPB. The overall sample was then used to conduct a structured equation modelling (SEM) on the direct constructs of the TPB and the latent variables based on the theoretical pathways of the TPB. SEM, unlike traditional regression methods, is hypothesis-driven, and a technique for confirmatory instead of exploratory analysis (Salkind, 2010). Thus, the decision to test for a specific moderating effect of interest (i.e., previous exercise behaviour) was determined a priori. Any other differences in demographic factors were regarded to be mediated by TPB constructs (Ajzen, 2020).

5.7 Results

Descriptive statistics (means and standard deviations) of all direct TPB constructs are shown in Table 5.2. These data are presented for the full sample and grouped by selected participant characteristics.

Table 5. 2

Descriptive Statistics (Means and Standard Deviations) for Direct TPB Constructs for the Full Sample and Subgroups

Demographic variables	n*	Mean scores (*SD*) on direct TPB constructs			
		Att	SN	PBC	Intention
All	446	3.96 (0.59)	3.76 (0.65)	3.84 (0.57)	3.40 (0.91)
Gender					
Male	120	4.01 (0.58)	3.82 (0.64)	4.00 (0.57)	3.46 (0.87)
Female	324	3.95 (0.56)	3.74 (0.64)	3.79 (0.56)	3.39 (0.91)
Age					
18-24 years	330	3.95 (0.57)	3.76 (0.64)	3.81 (0.55)	3.36 (0.89)
25-30 years	53	3.92 (0.58)	3.70 (0.67)	3.91 (0.62)	3.48 (0.87)
> 30 years	63	4.00 (0.67)	3.84 (0.72)	3.93 (0.64)	3.55 (1.03)
Ethnicity					
White	325	3.94 (0.58)	3.75 (0.63)	3.85 (0.56)	3.32 (0.92)
Asian	76	3.96 (0.60)	3.78 (0.67)	3.76 (0.59)	3.67 (0.78)
African	10	3.83 (0.43)	3.48 (0.64)	3.66 (0.53)	3.58 (0.66)
Middle Eastern	7	4.23 (0.60)	3.93 (0.51)	3.83 (0.55)	3.66 (1.12)
Others**	28	4.16 (0.58)	3.85 (0.84)	4.01 (0.71)	3.54 (0.95)
History of Concussion					
Yes	153	3.82 (0.63)	3.60 (0.68)	3.80 (0.60)	3.09 (1.00)
No	293	4.03 (0.54)	3.84 (0.63)	3.86 (0.56)	3.57 (0.81)

Contact Sports Participation					
Yes	116	3.88 (0.66)	3.75 (0.69)	3.89 (0.56)	3.43 (0.90)
No	330	3.99 (0.55)	3.77 (0.64)	3.82 (0.57)	3.40 (0.91)
Exercised regularly in past 12 months					
Yes	326	3.97 (0.57)	3.8 (0.64)	3.9 (0.53)	3.46 (0.87)
No	120	3.94 (0.62)	3.67 (0.68)	3.67 (0.64)	3.25 (0.99)
Education					
At least high school	6	4.00 (0.49)	4.04 (0.40)	3.7 (0.62)	3.37 (0.80)
Completed high school	202	3.95 (0.60)	3.76 (0.66)	3.80 (0.55)	3.40 (0.88)
Trade/technical/vocation training	34	3.99 (0.56)	3.6 (0.55)	3.86 (0.67)	3.27 (1.09)
Did not complete university	136	3.96 (0.54)	3.8 (0.63)	3.92 (0.56)	3.46 (0.86)
Associate Degree	7	4 (0.73)	3.86 (0.93)	3.94 (0.87)	3.34 (1.25)
At least a Bachelor's Degree	61	3.90 (0.65)	3.68 (0.70)	3.77 (0.56)	3.39 (1.00)
Gross Income					
$0-18,200	248	3.94 (0.54)	3.75 (0.64)	3.81 (0.54)	3.43 (0.89)
$18,201-$37,000	101	3.96 (0.65)	3.67 (0.66)	3.79 (0.60)	3.26 (0.95)
$37,001-$90,000	71	4.00 (0.43)	3.88 (0.69)	3.94 (0.60)	3.44 (0.91)
$90,001-$180,000	21	4.03 (0.43)	3.92 (0.45)	4.07 (0.52)	3.70 (0.71)
$180,001 and over	5	4.1 (0.62)	3.80 (0.89)	4.00 (0.93)	3.60 (1.36)

Note. Att = Attitude; SN = Subjective Norms; PBC = Perceived Behavioural Control.

*There was a negligible amount of missing data; Some of the n’s do not add up to the total N.

** Others include those who identified as belonging to more than 1 ethnic group, Aboriginal and Torres Strait Islanders, Pacific Islanders and South Americans.

Exploratory Factor Analysis

An EFA on a 50% split sample (*n* =221) helped to evaluate the dimensionality of the questionnaire in accordance with the theoretical constructs of the TPB. A Principal Axis Factoring method was used for extraction. As most of the factors had a correlation of >0.3 as expected for TPB constructs, an oblique rotation (Direct Oblimin) was used (Meyers et al., 2006).

Two of the items on controllability over the exercise participation were removed from the *perceived behavioural control* subscale due to low factor loadings on the pattern matrix. These items were "*The decision to participate in Active-Heads is beyond my control*" and "*Whether I participate in Active-Heads or not is entirely up to me*".

The EFA led to three factors with an Eigen value higher than 1 and explained 52% of the variance. Considering an alignment to TPB constructs and commonly recommended Eigen values, the 4th factor with an Eigen value close to 1 (0.927) was included. The final model was fixed to four factors (i.e., *attitudes, subjective norms, perceived behavioural control* and *intention*) and explained 74.1% of the variance. The extraction communality for all the items were sufficiently high (all > 0.3), indicating that the items retained were adequately correlated. The internal consistency was high for all factors with Cronbach's alpha ranging from 0.85 to 0.94. The naming of factors was consistent with the theoretical constructs underlying the TPB. Table 5.3 shows the descriptive data and factor loadings for all TPB items.

The KMO measure of sampling adequacy was 0.938 and Barlett's test of sphericity was statistically significant (p <.001). None of the correlations between mean factor scores were above 0.7, suggesting sufficient discriminant validity was demonstrated but the factors cannot be assumed to be orthogonal.

Table 5. 3

Mean, SD, and Pattern Matrix for Exploratory Factor Analysis of the TPB Questionnaire

Item	Mean (SD)	Factor 1 (Attitude)	Factor 2 (Intention)	Factor 3 (PBC)	Factor 4 (SN)	Extraction Communality
If I took part in Active-Heads, it would be positive.	4.05 (0.69)	0.858				0.738
If I took part in Active-Heads, it would be worth the time.	4.00 (0.71)	0.857				0.770
If I took part in Active-Heads, it would be sensible.	3.99 (0.81)	0.794				0.638
If I took part in Active-Heads, I would feel healthier.	4.10 (0.82)	0.789				0.614
If I took part in Active-Heads, it would be safe.	3.91 (0.86)	0.753				0.566
If I took part in Active-Heads, I would feel better.	3.96 (0.73)	0.738				0.676
If I took part in Active Heads, I would feel happy.	3.77 (0.78)	0.614				0.463
If I took part in Active-Heads, my symptoms would improve.	3.81 (0.76)	0.611				0.463
I plan to do Active-Heads	3.38 (1.00)		-0.929			0.853
The likelihood of me participating in Active-Heads is…	3.47 (0.95)		-0.927			0.813
I intend to do Active-Heads	3.45 (0.95)		-0.816			0.830
I expect to do Active-Heads	3.31 (0.97)		-0.751			0.733
I want to do Active-Heads	3.54 (0.93)		-0.605			0.626
I am confident of doing the activities in the Active-Heads program.	3.77 (0.83)			-0.931		0.902

I am confident that I can complete the Active-Heads program.	3.78 (0.83)			-0.756		0.693
I am confident that I can participate in the Active-Heads program.	3.82 (0.81)			-0.706		0.793
People like me would want me to participate in Active-Heads	3.85 (0.73)				0.915	0.786
People like me would be interested in participating in Active-Heads.	3.77 (0.73)				0.725	0.694
Most people who are important to me would be interested in participating in Active-Heads.	3.55 (0.89)				0.583	0.488
Most people who are important to me would approve of me participating in Active-Heads.	4.00 (0.77)				0.566	0.536
Cronbach's alpha	-	.92	.94	.92	.85	-
Eigen value	-	10.5	2.1	1.3	0.9	-

Note. n=221 (random split from overall study sample).

Extraction method: Principal axis factoring. Rotation method: Oblimin with Kaiser normalisation. Rotation converged in 6 iterations. Abbreviations: PBC perceived behavioural control, SN subjective norms; Bold numbers: emphasise highest loadings in a column

Confirmatory Factor Analysis

A CFA was carried out to establish the fit of the model using the second half of the random split sample (n = 227). Latent variables were determined by the four TPB factors that loaded on the pattern matrix in the EFA. Factor loadings of the latent to observed variables were all > 0.3, as recommended by Meyers et al. (2006). All the items included in the CFA had significant regression with their related latent variables. No modifications were made to the model fit as it was marginally acceptable for predictive analysis. The recommended fit indicators and fit indices for this model are shown in Table 5.4.

Table 5. 4

Goodness-of-Fit Indicators for Model

Indices	Absolute fit indices			Incremental fit indices	Parsimony fit indices
	CMIN/df	CMIN *p* value	RMSEA	CFI	PNFI
Current model	2.35	$p < .001$	0.07	0.93	0.77
Recommended value	1-2	$p > .01$	<0.10	>0.95	>0.50

Abbreviations: *CMIN* minimum discrepancy, *RMSEA* root mean square error of approximation, *CFI* comparative fit index, *PNFI* parsimony-adjusted normative fit index

Correlation of TPB constructs

The correlation matrix in Table 5.5 shows the relationship of all the TPB constructs. All constructs demonstrated a positive significant relationship with one another, except for indirect PBC, which correlated only with the other indirect constructs but not direct constructs.

Table 5. 5

Correlates of TPB Constructs

Measures	1	2	3	4	5	6
1. Direct Attitude						
2. Indirect Attitude	.50*					
3. Direct Subjective Norms	.66*	.57*				
4. Indirect Subjective Norms	.45*	.44*	.52*			
5. Direct Perceived Behavioural Control	.51*	.51*	.56*	.29*		
6. Indirect Perceived Behavioural Control	.08	.15*	.09	.20*	.03	

7. Intention	.48*	.49*	.62*	.41*	.47*	.14**

Note. N = 446.

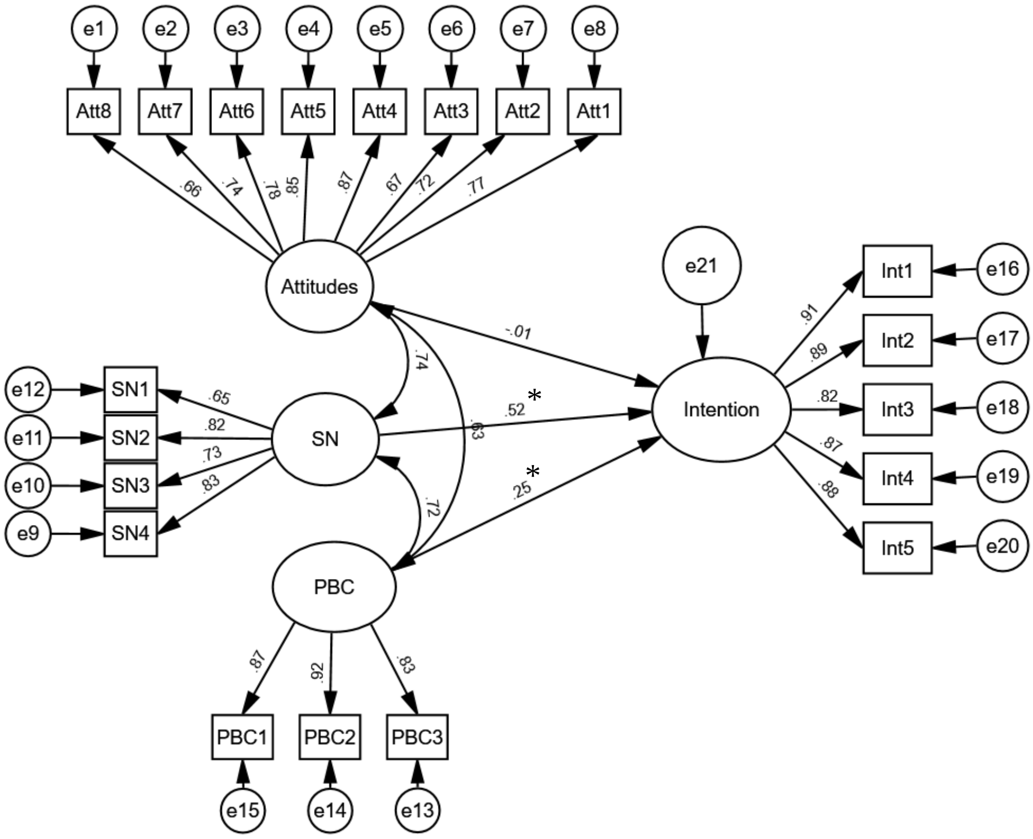
**p* = <.01 ***p* = .004

Structured Equation Modelling

Using the entire sample from the study (*n* = 459), structured equation modelling (SEM) was used to determine the predictive power of the latent constructs in the model. General guidelines for path analysis recommend at least 10 cases per variable (Wolf et al., 2013). Therefore, a minimum N size of 200 would be necessary given the 20 observed variables included in the model. Considering the small number of random missing values dispersed across the data, the "Estimate means and intercept" option was selected on AMOS before the model was analysed. Figure 5.2 illustrates the model with the standardised regression weights for all the key observed and latent variables. Both the regression weights for *subjective norms* and *perceived behavioural control* were significant, but not for *attitude*. Similar to prior reviews on the TPB (Hagger et al., 2002; Sutton, 1998), the overall model in this study accounted for 50.6% of variation in *intention* to participate in the exercise rehabilitation program.

Figure 5. 2

Structured Equation Modelling of TPB constructs



Indirect constructs are not shown in the model for ease of intepretation. All numbers above arrows indicate the standardised regression weights for each pathway.

The numbers above the bidrection arrows indicate the covariance between the constructs.

**p* = <.001

Influence of Previous Exercise Behaviour

To test for any moderating effects of past exercise behaviour on *intention*, a series of chi-square difference tests were carried out on the beta-weights for the pathways comparing the variable (i.e., model with previous exercise behaviour vs. model without previous exercise behaviour). The overall model was not significantly different for both groups. Table 5.6 shows the beta weights of each of the direct constructs in the two compared models. Only *subjective norms* were a significant predictor of *intention* for both groups. For those who did not report previous exercise behaviour, stronger *attitudes* were predictive of lower *intention* while *perceived behavioural control* was predictive of higher *intention*.

Table 5. 6

Comparison of Regression Weights Between Groups

Constructs predicting intention	Beta for previous exercise behaviour	Beta for no previous exercise behaviour
Attitudes	0.13	-0.49*
Subjective Norm	0.52**	0.78**
Perceived Behavioural Control	0.07	0.49**

Note. * $p < .01$, ** $p < .001$

Feasibility Factors for Exercise Participation

Participants were asked about features that they would consider to be desirable for an exercise rehabilitation program such as *Active-Heads*. The proportion of responses indicating *agree/strongly agree* to the questions are shown in Table 5.7. The most desirable feature was personalisation of the program according to individual fitness levels (91.4%). Most participants were also in favour of a combination of aerobic and resistance exercises (81.4%) and being guided by a trained professional (86.2%). A majority of participants (86%) also identified that they would participate in such programs if it was offered for free. Slightly more than half (62.8%) indicated that meeting others with a similar injury would encourage their participation in such programs, while close to half (49.8%) stated that a home-based program would increase their participation. For items on exercise intensity and ideal duration of program, only a small proportion of participants felt that the program could be too time consuming (21.8%) or too intensive (11.9%).

Table 5. 7

Responses to Desirable Features of Exercise Program

Items	n	Mean (SD)	Percentage of A/SA*
The idea of *Active-Heads* being personalised to my fitness level makes me want to do the program.	441	4.27 (0.69)	91.4%
The idea of having a professional guiding me in *Active-Heads* makes me want to do the program.	441	4.15 (0.73)	86.2%
I would be interested in attending a trial session of the *Active-Heads* program before I decide on committing to it.	444	4.14 (0.85)	86.1%
I would participate in the *Active-Heads* program if there was no cost (e.g., Medicare paid)	444	4.34 (0.84)	86.0%
The idea of getting health and fitness information from *Active-Heads* makes me want to do the program.	441	3.98 (0.83)	82.3%
The idea of having a combination of aerobic and strength training in *Active-Heads* makes me want to do the program.	441	4.05 (0.75)	81.4%
Watching a demo video of *Active-Heads* would help me decide if I can commit to it.	444	4.03 (0.85)	81.3%
The idea of meeting other people with a similar injury like me in *Active-Heads* makes me want to do the program.	441	3.61 (1.00)	62.8%
There would be a better chance for me to participate in *Active-Heads* if it was home based.	444	3.40 (1.06)	49.8%
The *Active-Heads* program sounds too time-consuming for me.	444	2.75 (0.93)	21.8%
The *Active-Heads* program sounds too intensive for me.	444	2.46 (0.90)	11.9%

Note. *N* =444 (some responses were missing for some items).

*Percentage of overall agree (A)/strongly agree (SA) responses. All items were assessed on a 5-point Likert scale with 1 =*strongly disagree* and 5 = *strongly agree*.

Barriers to Exercise Participation

To assess barriers to participating in such exercise rehabilitation programs, participants were given a list of common barriers identified from the exercise literature (Table 5.8). The greatest barriers to participating in a program such as *Active-Heads* were perceived to be a lack of time (74.1%) and work commitments (66.7%). A lack of transportation to exercise locations (26.4%) and lack of interest (26.1%) were reported as hurdles for exercise participation in a quarter of the participants. Participants were also less likely to prefer other exercise options (14.2%) or seek other types of treatment (13.5%) as an alternative to a program like the *Active-Heads*.

Table 5. 8

Responses to Potential Barriers to Participation in Exercise

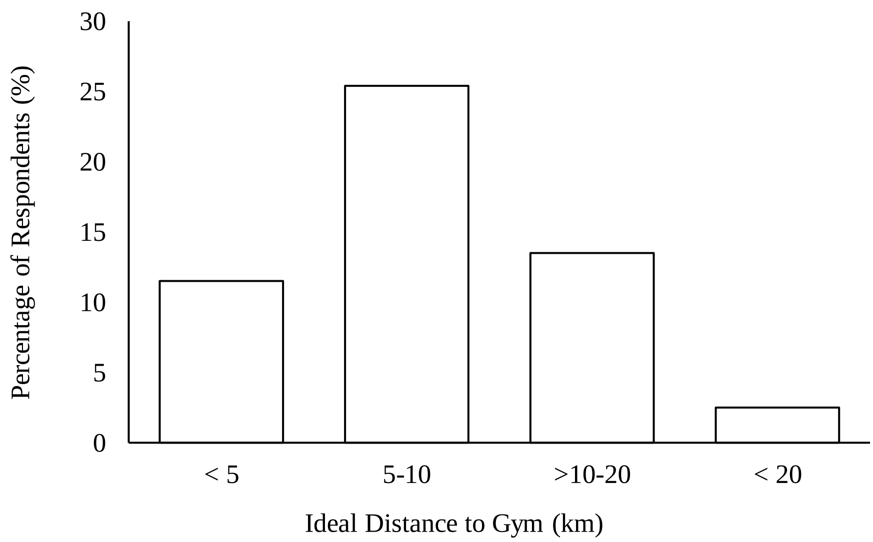
Potential barriers to participate	Yes responses (%)
Lack of time	74.1
Work commitments	66.7
Distance from gym	55.3
Health concerns	42.3
Too lazy	29.6
Lack of transportation	26.4
Lack of interest	26.1
Prefer more options for exercise	14.2
Prefer other types of treatment	13.5

Note. Participants were allowed to respond to more than 1 item.

Follow up questions were asked about the maximum distance participants would consider travelling to participate in an exercise program like *Active-Heads*, the time they would be willing to spent exercising each week, and the preferred overall duration of a program. These responses are presented in Figure 5.3, 5.4 and 5.5. Overall, most participants report that they would consider travelling up to 5-10 km to the gym, exercise for 1-2 hours per session and prefer a program lasting 3- 4 weeks.

Figure 5. 3

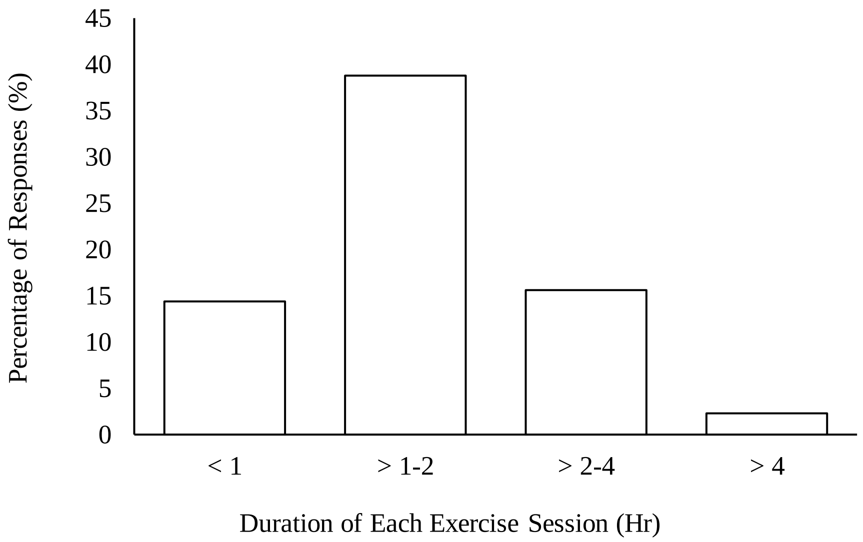
Percentage of Participants Indicating Ideal Distance to Exercise Location



Note. n = 253 (only those who responded to distance from the gym being a barrier were asked this question).

Figure 5. 4

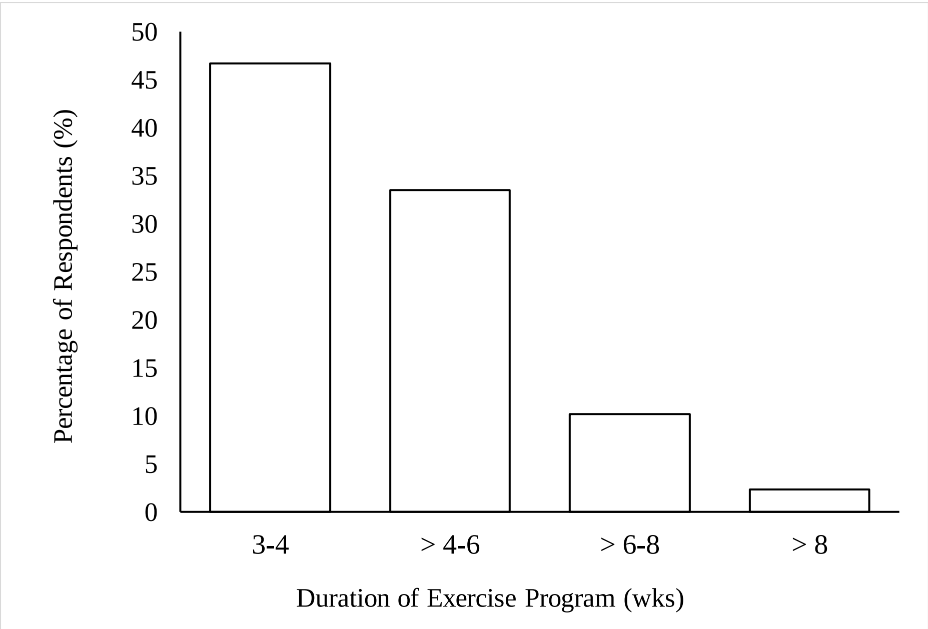
Percentage of Participants Indicating Ideal Duration for Exercise Session



Note. n = 338 (only those who responded to lack of time as a barrier to exercising were asked this question).

Figure 5. 5

Percentage of Participants Indicating Ideal Duration of Exercise Program



Note. *n* = 441

5.8 Discussion

This study explored the application of the TPB on *intention* to participate in a hypothetical PPCS exercise rehabilitation program after a concussion. The first hypothesis (***H10***) that positive *attitudes* would be predictive of stronger *intention* to participate in an exercise intervention after a concussion was not supported. The second hypothesis **(*H11***) that *subjective norms* would be predictive of stronger *intention* to participate in an exercise intervention after concussion was supported. The third hypothesis (***H12***) that higher *perceived behavioural control* would be predictive of stronger *intention* to participate in an exercise intervention after a concussion was supported. Finally, the fourth hypothesis (***H13***) that past behaviour would have a moderating effect on the TPB constructs towards *intention* to exercise participation was partially supported. Overall, the model accounted for close to half of the variance in *intention* to participate in the PPCS exercise rehabilitation program, a much higher variance than that generally found in TPB studies (Armitage & Conner, 2001; Godin & Kok, 1996). This study drew from exercise rehabilitation literature and assumed that the views typically held about exercise rehabilitation for other conditions – such as cancer – would also hold for concussion. However, the findings do not seem to entirely support this idea; rather, the views about exercise rehabilitation for PPCS did not follow the trends observed for exercise rehabilitation for other conditions. This idea is explored further in the following sections, which also provide a discussion of the findings for each hypothesis.

Attitudes

Contrary to previous findings from exercise rehabilitation literature, this study found that having positive *attitudes* towards the *Active-Heads* program did not translate to strong *intention* to participate in the program. The findings suggest that while people believe in the effectiveness of such exercise programs, the onset of a concussion could be a critical factor in decisions for rehabilitation. Further exploration of the indirect *attitude* constructs (i.e., beliefs about exercise and evaluation of the outcomes) support this finding by indications that people held favourable beliefs about such programs and acknowledged the potential for benefits, yet these *attitudes* did not follow through to their *intention*. In a study on attitude formation and predictability of future behaviour, Glasman and Albarracín (2006) found that *attitudes* could only be reliable predictors of future behaviours when people were confident about the behaviour and had sufficient behaviour relevant information through personal experience. As the closest proxy measure for confidence, higher scores in the *perceived behaviour control* measure indicated that the participants could have felt confident about participating in the *Active-Heads* program based on the program description, influencing their attitudes positively. However, a lack of actual participation in such programs and an assumption of considerable risks after a concussion could possibly explain why positive *attitudes* did not translate to *intention* to participate in such a program in this study.

It has been suggested that *attitudes* may not predict *intention* if the constructs to measure attitude lack accuracy or specificity (Godin & Shephard, 1986; Tornikoski & Maalaoui, 2019). For example, attitudes that are not specifically defined according to the target behaviour may not always be reliable predictors of *intention* (Godin & Shephard, 1986). However, in the present study, all the *attitude* items in the survey referred to *Active-Heads* after a detailed description of the program to ensure both *attitude* and *intention* was addressing a clearly specified rehabilitation behaviour. Muschalik et al. (2019) found discrepancies between explicit and implicit attitudes to also lead to poor predictability in exercise studies. This study mitigated this by the inclusion of explicit questions (e.g., measures of instrumental and affective attitudes) and implicit questions (e.g., measures of indirect attitudes). The moderate, but significant correlations between *attitude* measures and other TPB constructs is also consistent with other studies (Armitage & Conner, 2001; Hagger et al., 2002), lending support for acceptable discriminant and content validity of the survey sub-scales. Thus, in this context, it is possible to deduce that more attention needs to be given to shaping attitudes specific to PPCS exercise rehabilitation even when people may have generally positive *attitudes* about exercise rehabilitation.

Subjective Norms

TPB research on exercise has generally found that *subjective norms* are a poor predictor of exercise *intention* (Godin & Kok, 1996; Hausenblas et al., 1997; Sommer, 2011). Blue (1995) reasoned that people view the decision to exercise as their own responsibility, and that such *intentions* are less contingent on the views of others. However, the findings from this study suggest otherwise. It appears that participants were more likely to be influenced by the *subjective norms* specific to PPCS rehabilitation. These findings mirror other TPB studies on exercise *intention* specific to clinical populations (Blanchard et al., 2002; Courneya et al., 2001; Hunt-Shanks et al., 2006). This suggests that exercise for recreation or for risk-prevention may entail different considerations as opposed to exercise for treatment where perceived risks and benefits may play a stronger role.

The moderate, positive correlation between direct and indirect constructs of *subjective norms* suggests that participants placed considerable importance on both what similar others would think (i.e., direct constructs) as well as the perceptions of important referent groups such as athletes, doctors, and family members (i.e., indirect constructs). The significance of what referent groups think also suggests that in the context of post-concussion, people may be more likely to defer rehabilitation decisions to others with better knowledge or experience. Studies on patients with cancer have found *subjective norms* to be just as predictive of other TPB constructs in *intention* to participate in exercise rehabilitation (Courneya & Friedenreich, 1999; Hunt-Shanks et al., 2006). These findings further support the idea that social influences towards rehabilitative exercise can vary depending on the context and purpose. While the general understanding is that individuals do not usually identify *subjective norms* as important to their decisions, perceptions of social networks and referent groups appear to play a greater role in exercising for rehabilitative purposes. In other words, people may be more likely to participate in exercise rehabilitation after PPCS if credible and important referent groups have favourable views and are in support of exercise.

Several studies contend that *subjective norms* items may not adequately capture the facets of social influence relevant to a health behaviour (Armitage & Conner, 2001), suggesting possible explanations for missed findings for this variable. While Ajzen (2019) recommends that measures of *subjective norms* should include both perceptions of typically *performed behaviours* by others (i.e., descriptive norms) and perceptions of behaviours typically *approved or disapproved* by others (i.e., injunctive norms), this study only used injunctive norms. Studies have asserted that the use of injunctive norms are adequate for predicting *intention* (Rhodes & Courneya, 2003). Moreover, the internal consistency for the SN items was high (Cronbach's alpha = 0.84), and in line with recommendations by Francis et al. (2014), indicating that issues with content validity were less likely. Typically, studies attribute problems with item design to the lack of predictive utility for *subjective norms* but it is noteworthy that this study found perceptions of significant others to be the best predictor of participation in PPCS exercise rehabilitation.

Perceived Behavioural Control

The exercise literature suggests that *perceived behavioural control* is a strong predictor of *intention* (Hagger et al., 2002). In the present study, *perceived behavioural control* was a significant predictor of *intention* to participation in PPCS exercise rehabilitation, but the relationship was weak. Based on the item scores, participants indicated high levels of confidence in participating in *Active-Heads,* but this was not a strong predictor of participation intent in a rehabilitative context. A possible explanation for this weak relationship could be drawn from previous findings highlighting parallel trends between *perceived behavioural control* and *attitudes* (Hagger et al., 2002). Just as positive *attitudes* about the program did not translate to participation *intention*, it may be likely that a perception of high confidence levels in personal ability to exercise did not eradicate trepidations about the potential risks of actual participation in the described exercise program after a concussion.

It is important to note that the *perceived behavioural control* items retained for the final analysis in this study were measures of self-efficacy towards the target behaviour. Two items on self-control were originally included for a more comprehensive measure of the construct, but both these items were removed due to poor loadings during factor analysis. While (Ajzen, 2019, 2020) asserts that self-efficacy is an adequate and reliable proxy measure for *perceived behavioural control*, and Rhodes and Courneya (2003) found self-efficacy to be more predictive of *intention* than control, there is a possibility that the construct did not show strong predictability due to not assessing important facets of *perceived behavioural control* such as resources and opportunities (Ajzen & Madden, 1986).

A closer inspection of the indirect construct for *perceived behavioural control revealed* that the overall average scores were the lowest relative to the other indirect measures. A possible explanation for this is that in this study's sample, people were less likely to perceive having control over factors like time and motivation. However, the lack of correlation with the other direct TPB constructs could also suggest that the control beliefs assessed in this study may be exploring facets that are considerably different from, and unrelated to, rehabilitative exercise. For example, the indirect measures focussed on the ability to overcome potential hurdles (e.g., time constraints, lack of motivation), which could depend on other factors (e.g., need to work, other health problems), and this might not be directly related to the high self-confidence to participate in PPCS rehabilitation.

Influence of Past Behaviour

Previous findings on moderating factors have found past behaviour to be predictive of *intention* over and above the TPB constructs (Hagger et al., 2002; Rhodes et al., 2002). However, this study did not find previous exercise behaviours to have a moderating effect on the overall predictive model. For those who reported previous exercise behaviours, the beta-weights in the model suggest that the strength of the relationship towards intention to exercise was positive for all the TPB constructs although only *subjective norms* was significant. It is possible that regular exercising provided people better experiences of exercise intensity and exertion. However, these experiences coupled with general perceptions about conservative rehabilitative approaches for PPCS could have resulted in people considering exercise rehabilitation as too risky after a concussion despite previous exercise habits (Salisbury et al., 2017). Another possibility is that those with current exercise habits may find less of a need to undertake a specific exercise program for rehabilitation and be more inclined towards continuing their normal exercise regime. However, this is less likely given that a weak relationship was observed between *attitudes* about exercise and *intention* in this group.

For those who did not report any previous exercise behaviours, the significant negative relationship between *attitudes* and *intention* further supports the notion that those who tend to be sedentary are less likely to have positive *attitudes* towards the beneficial outcomes of exercise. An implication of this finding is the need to provide adequate advice to raise awareness on the safety and effectiveness of active rehabilitation options among individuals without previous exercise habits. This could be useful in shaping more positive attitudes about exercise when consideration rehabilitation options for PPCS. Unexpectedly, a significant positive relationship was observed between *perceived behavioural control* and *intention* among those with no previous exercise behaviour. A likely interpretation for this finding is that those who are less likely to exercise regularly may also be less competent to appraise the intensity or difficulty of such exercise programs based on the provided description. Thus, this group of (inactive) participants could be indicating a false sense of inflated confidence and thus, reported stronger *intention* to participate in the program.

Finally, *subjective norms* were observed to be significant predictors for both the group who reported previous exercise behaviour and those who did not. This is an important finding that suggests that it could be worthwhile to invest in education efforts and improving knowledge on exercise rehabilitation for wider groups of the community that includes key referent groups (e.g., coaches, doctors). Key messages about the potential of exercise rehabilitation could be disseminated through these influential referent groups for optimal effects.

Feasibility and Barriers for Future Exercise Rehabilitation Programs

A secondary aim of this study was to explore the features of exercise rehabilitation that could increase appeal to individuals and potentially improve participation in PPCS rehabilitation. It was encouraging to find that most of the preferences highlighted in this study were in line with current recommendations for exercise for PPCS in the literature (e.g., individual calibration, aerobic and resistance exercises, supervision). With most participants indicating cost as an important factor in such rehabilitation programs, this remains an essential consideration for future rehabilitation programs. A considerable number of participants did *not* find the social benefits of meeting others with similar problems to be a benefit. Taken together with the fact that only about half of the participants indicated the preference for a home-based program, there could be some value in promoting the social and interactive benefits of programs in the gym or at a specified location. For example, findings on the psychological advantages obtained through normalising of issues and the motivational aspects of exercising in groups can be emphasised when promoting such exercise rehabilitation programs.

This study also explored potential barriers to participating in exercise rehabilitation programs. In line with previous exercise studies (Ebben & Brudzynski, 2008; Tappe et al., 1989), the strongest barriers were not having sufficient time for exercise and work commitments. Exercise rehabilitation can be offered flexibly to accommodate working individuals or offer more variety in the mode of program (i.e., home, gym based, online). Given that many people at risk for concussion are of working or schooling age (Zhang et al., 2016), this is an important consideration. Participants were also less inclined to consider alternatives to a program like *Active-Heads*, suggesting that there is potential for a good uptake in such programs when other factors are taken into consideration. For example, follow-up questions on the common barriers to exercising suggested that an ideal program could be in a gym that is not more than 10km from the place of residence, last for 1-2 hours per session, and preferably span 3-4 weeks. Keeping such factors in mind in promoting and implementing exercise rehabilitation could be invaluable.

5.8.1 Implications of Findings

While the sufficiency assumption of the TPB posits that the measured constructs should be adequate in measuring *intention* accurately (Ajzen, 2011), as with all TPB studies (Sniehotta et al., 2014), it is important to acknowledge that a considerable proportion of variance is not accounted for by the TPB. For example, it is possible that other important factors such as personal identity could also be at play. Specific to the context of this study, the sociocognitive constructs assessed were not exhaustive, but they nevertheless provide a valuable starting point to understand factors around engagement in rehabilitation, and plan and design interventions that will appeal to the target audience (Hoegy, 2012).

The findings from this study suggest that despite positive *attitudes*, individuals were less likely to participate in exercise rehabilitation for PPCS. While *perceived behavioural control* such as self-efficacy was predictive towards *intention, subjective norms* were the strongest predictor of *intention* to participate in exercise rehabilitation after a concussion. The unique feature of the ability to understand and modify TPB constructs to increase the likelihood of a behaviour cannot be understated here.

First, it is not general *attitudes* towards exercising that may need to be modified but rather *attitudes* and beliefs about exercising after a concussion for rehabilitative purposes. More specific education efforts about the potential benefits and the restorative capabilities of exercise programs are necessary to dispel some of the misconceptions and minimise the prevailing views inflating the risks of exercising after a concussion. In line with current concussion management guidelines, the importance of a stepwise approach or gradual commencement of activity that can be carried out safely under professional supervision needs to be highlighted to allay any concerns of risk.

Second, *perceived behavioural control* was high for the sample in this study and predictive of *intention*, indicating higher confidence in themselves if required to participate in such exercise rehabilitation programs. While individuals can be confident, it is also important to further reassure them that rehabilitative exercise in a program like *Active-Heads*, as noted in findings from Study 1, is usually closely monitored and progressed at a pace of the individual's fitness levels. This study did not measure self-control factors but noted lower scores in the indirect *perceived behavioural control* measures (i.e., control beliefs). As the control beliefs were intended to assess how much control people believe that they had over participation in exercise rehabilitation, the findings highlight the importance to consider the needs of people within the design of exercise rehabilitation programs. For example, flexible options that allow people to exercise at home at their own convenience could allow people to have more power over the decision to choose such rehabilitation.

Third, *subjective norms* were found to be the most important predictor in this study. Given the importance of the views of significant others in exercise rehabilitation, the need to target education and awareness efforts at the general community that includes influential institutional factors is paramount. The community encompasses athletes, parents, healthcare providers and those who have close relationships with anyone who may be at risk for concussions. By the promulgation of the benefits of such programs in a widespread fashion, it is expected that the message about the potential of exercise rehabilitation can be delivered to those who need it. Another key implication from this study is the importance of referent groups such as athletes or doctors. As role-models, athletes can be part of promotional campaigns to demonstrate the effects of exercise rehabilitation for concussion. Doctors were found to be influential referents in this study, and along with other healthcare providers (e.g., physiotherapists, psychologists) can be a catalyst to highlight the potential benefits of such programs by having conversations about exercise and its potential benefits in this context.

5.8.2 Future Directions

The findings from this study provide some insights into sociocognitive factors that can be targeted to improve knowledge and uptake of PPCS exercise rehabilitation programs. Exercise can be effectively incorporated into a multidisciplinary rehabilitation plan for individuals who may be suitable if education programs can address any misconceptions and the message is reinforced by influential personnel. Creating options for rehabilitation can also place more choices in the hands of patients who have other hurdles to consider. While this study sheds some light on preferences and barriers to exercise, the importance of striking a balance between what participant wants and what the empirical evidence shows about effective exercise should also be acknowledged if such findings are to be taken further.

Given the possibility that perceived risks and benefits could be key factors specific to rehabilitative exercise, future studies can consider exploring models such as the Health Belief Model in a similar context. Further, studies exploring factors that influence participation in PPCS rehabilitation could use a prospective longitudinal design. If programs like *Active-*

Heads become available in the future, the inclusion of a measure of actual behaviour as part of addressing the intention-behaviour gap can be useful. Studies of factors moderating the TPB have found that stability of *intention* may change over time with the availability of new information, personality, and other demographic factors (Downs & Hausenblas, 2005), and these can influence actual behaviour. Incorporating such variables into future studies can provide a better illustration of factors that can be addressed to improve participation in exercise rehabilitation.

Future studies can also consider focusing on understanding how patients view exercise after a concussion and specific reasons for such beliefs. A small proportion (13.5%) of participants in this sample suggested that they would prefer other alternatives, but this could be higher if assessing patients with an actual concussion (vs. imagined concussion). Patients with actual injuries may not be in a position to choose a specific approach such as exercise and concerns about risks/benefits could play a bigger role. Finally, studies using similar methodologies can also explore the predictive value of more specific factors such as clinical recovery and safety as opposed to exercise in general.

5.8.3 Strengths

To the best of the author's knowledge, this is the first study to use the TPB as a framework to understand decisions towards PPCS exercise rehabilitation. Specific to this context, the findings have not only provided a better understanding of factors behind decisions to participate in exercise rehabilitation but have also enabled targeted options to modify one or more of these constructs for favourable outcomes. It is also expected that this study will set in motion more expansive TPB studies that consider other influential factors (e.g., age, gender) and modalities of rehabilitation to ultimately improve treatment of PPCS.

5.8.4 Limitations

First, the validity check for inclusion in this study was those who completed more than 50% of the questions. Potentially useful information from those who had trouble reading and understanding the questions could have been omitted from the analysis. While elicitation studies in the form of focus groups are usually conducted in TPB studies to determine common and relevant beliefs as part of developing indirect constructs, this study drew concepts from empirical literature on TPB and general exercise. As such, the beliefs being accessed may have not been truly reflective of the population in this study.

Second, this study was carried out using a hypothetical exercise program where participants had to imagine having had a recent concussion. It must be acknowledged that only a third of participants reported an actual history of a concussion, thus findings may not generalise to a clinical population. However, it is not uncommon for exploratory studies to draw inferences about concussion from vignette studies (Sullivan & Edmed, 2012; Sullivan & Edmed, 2016; Sullivan et al., 2013). Since concussion is an acute injury that can affect people across the lifespan, it may be argued that the views of people who might be injured in future and offered exercise for PPCS, can be considered relevant to program design. A recent study by Skeel et al. (2021) used hypothetical injury scenarios to determine accuracy in concussion management practices, lending support that such designs have its place in furthering important knowledge on PPCS rehabilitation.

Third, the use of the hypothetical *Active-Heads* program suggests that the responses could be pertaining to *intention* to participate in a similar exercise program that adopts the principles of gradual, sub-symptom threshold aerobic and resistance exercises. As such, the findings from this study cannot be generalised to other types of exercise programs and further research may be required to explore *intention* to participate in other exercise modalities.

Conclusion

The findings from this study aimed to better understand personal factors underlying the *intention* to participate in PPCS exercise rehabilitation. Using the TPB as a theoretical framework, it was found that *subjective norms* were the strongest predictor of *intention* in this sample. *Perceived behavioural control* was also a significant predictor with a weaker relationship while positive *attitudes* did not predict *intention* to engage in exercise for PPCS. It is possible that misinformation and assumed risks about exercising after a concussion affected people's *intention*. Future studies can focus on addressing these misconceptions, leverage the influential power of significant others and incorporate the preferences highlighted in intervention design. A strength of this study is the use of a theoretical framework to unpack potential factors that determine rehabilitative decisions and future intervention design consideration. Going forward, such approaches may be instrumental to study participation characteristics using a structured model as research continues to propose more rehabilitative options. Unlike many studies using regression to analyse TPB constructs (Ajzen, 2019), this study adopted the use of SEM to identify latent variables, covariance and accounted for measurement errors.

5.9 Chapter Summary

This aim of this chapter was threefold; first, to understand the personal sociocognitive constructs that can potentially influence the decision to exercise using an extended theory of planned behaviour; second, to identify features of an exercise rehabilitation program that could improve participation; and third, to identify potential barriers to participating in exercise rehabilitation after a concussion. The application of the TPB in this particular context revealed that positive *attitudes* towards exercise may not translate to *intention* to participation in PPCS exercise rehabilitation. Possible reasons for this could be an underlying misinformed risk associated with exercising after an injury or concussions not being viewed as serious enough to warrant exercise rehabilitation. *Perceived behavioural control* was found to significantly predict *intention* to exercise while *subjective norms* were the strongest predictor of intentions. It appeared that providing more flexible exercise options may empower patients when making rehabilitative decisions and the most convincing manner to get the message about exercise rehabilitation through to the community may be through referent groups such as athletes and doctors. The preferences for exercise rehabilitation highlighted in this study mirrored most of the existing recommendations for PPCS exercise interventions but keeping the cost of such specialised programs affordable remains an essential consideration. Common barriers to participating in exercise rehabilitation were not having enough time and having work commitments. Ultimately, these findings illuminate the need for future education efforts to demonstrate that exercise after a concussion can be safe, to have more flexible rehabilitation options for patients and to choose the right messenger for the message to have a greater impact.

Chapter 6: General Discussion

6.1 Chapter Introduction

This final chapter summarises the key findings from the three studies. An integration of the critical aspects of each study will then follow before theoretical and practical applications from this research program are addressed. The thesis started with an overview of how PPCS is a health problem that is challenging to diagnose and expensive to treat. Amidst current guidelines to take a multimodal approach for PPCS rehabilitation, an emerging view expressed that exercise was promising as a pan-domain rehabilitative option (Silverberg et al., 2020), could have wide ranging benefits, and be more accessible than other options. However, a lack of clear and well-defined exercise guidelines was a problem that needed addressing before considerations for wider implementation. Next, the research focused on exploring factors that could possibly underlie the lack of uptake of PPCS rehabilitation in the community. Drawing from the literature on knowledge translation and intervention design (Chandler et al., 2016; Colquhoun et al., 2017; Lenfant, 2003; Rubio et al., 2010; Woolf, 2008), it was hypothesised that knowledge gaps about concussion and rehabilitation as well as personal factors could offer some clues for the chasm between research and application.

6.2 Summary of Findings

6.2.1 Study 1

The first study was a systematic review undertaken to identify if the evidence from RCTs supports exercise for PPCS and identify the exercise parameters with the most support in the literature. Using clearly defined parameters from the exercise literature, the review used the *FITTT* principle to elucidate the key features in such programs. Until now, most studies on exercise for post-concussion rehabilitation have utilised similar parameters as observed in the systematic review, but it can be argued that this selection was made prematurely, including before variations were tried and reviewed to determine the best possible option. Further, the developers of new programs of exercise for PPCS did not have guidelines to use, and most studies did not use a framework for describing their approach which has presented challenges for replicability. Through the application of the FITTT principles, this review found that potential benefits for PPCS can accrue from four days of exercise per week for 10-15 minutes, commencing at an initial intensity of 50% HR with progressive increments to 80% HR, and that HR measurement should be complemented with subjective exertion measures such as a visual analogue scale [VAS]. An overall program duration of at least 4 weeks was ideal; but it could be more efficient for structured programs to be extended only if the patient needs it. In other words, it is recommended that patients could stop exercising at the prescribed levels if they became asymptomatic and given instructions to proceed with safe physical activity at a time and place that is personally convenient. It was emphasised that the litmus test to partake in exercise rehabilitation was a physical examination and an initial exercise threshold test to determine safety and suitability. The review also found that any modality of exercise that allowed the patient to maintain and progressively increase cardiovascular intensity (measured using HR and VAS) was acceptable. In line with current concussion management guidelines, it was also recommended that any exercise rehabilitation be commenced after 24-48 hours of rest, and only after medical clearance was granted.

6.2.2 Study 2

The second study explored the current state of knowledge and *attitudes* about concussion and rehabilitation in the community ($n = 224$). This study was novel for being the first of its kind in an Australian context and for including a measure to assess knowledge about PPCS rehabilitation. The study found that higher concussion knowledge and safer *attitudes* towards concussions were found in an Australian community sample as compared to previous studies using similar measures. However, common misconceptions about concussions such as symptom persistence and a perception of riskier *attitudes* among athletes persisted. Rehabilitation knowledge was also found to be centred around approaches such as rest and minimising exertion with only about 2% of participants suggesting exercise or physical activity as a possible rehabilitation option.

6.2.3 Study 3

The third study explored personal factors that could affect a person's decision to participate in PPCS exercise rehabilitation (*n* = 459). Using the theory of planned behaviour, this study examined how *attitudes*, *perceived behavioural control* and *subjective norms* could influence the *intention* to participate in a hypothetical PPCS exercise rehabilitation program (i.e., *Active-Heads*). This study found that participants had generally positive *attitudes* towards PPCS exercise rehabilitation, but these *attitudes* did not predict *intention* to participate in such rehabilitation programs. *Perceived behavioural control* was predictive of *intention* while the strongest predictor was *subjective norms*, suggesting that people in this sample placed importance on what significant others thought when making decisions for PPCS exercise rehabilitation. An important finding from this study was that exercise to prevent risk can entail very different determinants as opposed to exercise for treatment. Factors such as perceived risk and benefits of the exercise program may play an important role in a clinical context.

6.2.4. Integration of Findings

The aims of this research program were threefold; first, to identify a set of predefined exercise parameters based on evidence based PPCS exercise rehabilitation; second, to explore the current knowledge and attitudes about concussion and exercise rehabilitation in the general community; and third, to investigate a set of sociocognitive constructs that could influence the likelihood of participation in PPCS exercise rehabilitation programs. Figure 6.1 illustrates how findings from these three studies can be useful to address some of the potential gaps in knowledge translation between PPCS rehabilitation and potential options that can be made available to the community.

The first study identified exercise parameters that can be used in subsequent research. Evaluating the efficacy of the exercise parameters recommended in the first study could be a precursor to studies adopting such exercise interventions for much wider population groups. Both knowledge translation and intervention design studies highlight the importance of defining what rehabilitation entails as a crucial first step (Colquhoun et al., 2017; Lenfant, 2003). The findings from the first study can thus be useful to develop a standard set of exercise research parameters. The second study supported the idea that if these programs are found to be effective and can be rolled out, community education may be needed to overcome the widely held view that rest is best for PPCS. It is logical to assume that people cannot consider exercise as an avenue for rehabilitation if they do know about such options or its effectiveness in the first place. Finally, the third study helped to advance knowledge transfer gaps by highlighting that knowledge about rehabilitation alone may not be sufficient. Personal factors such as *attitudes*, *perceived behavioural control* over exercising and *subjective norms* can play a considerable role in the final rehabilitative decisions. More importantly, an important finding was that having positive *attitudes* about exercise did not translate to higher likelihood of participation in such rehabilitation. Rather, it is more important to marry education efforts about rehabilitation with the source of the messaging and by clarifying the safety of such programs.

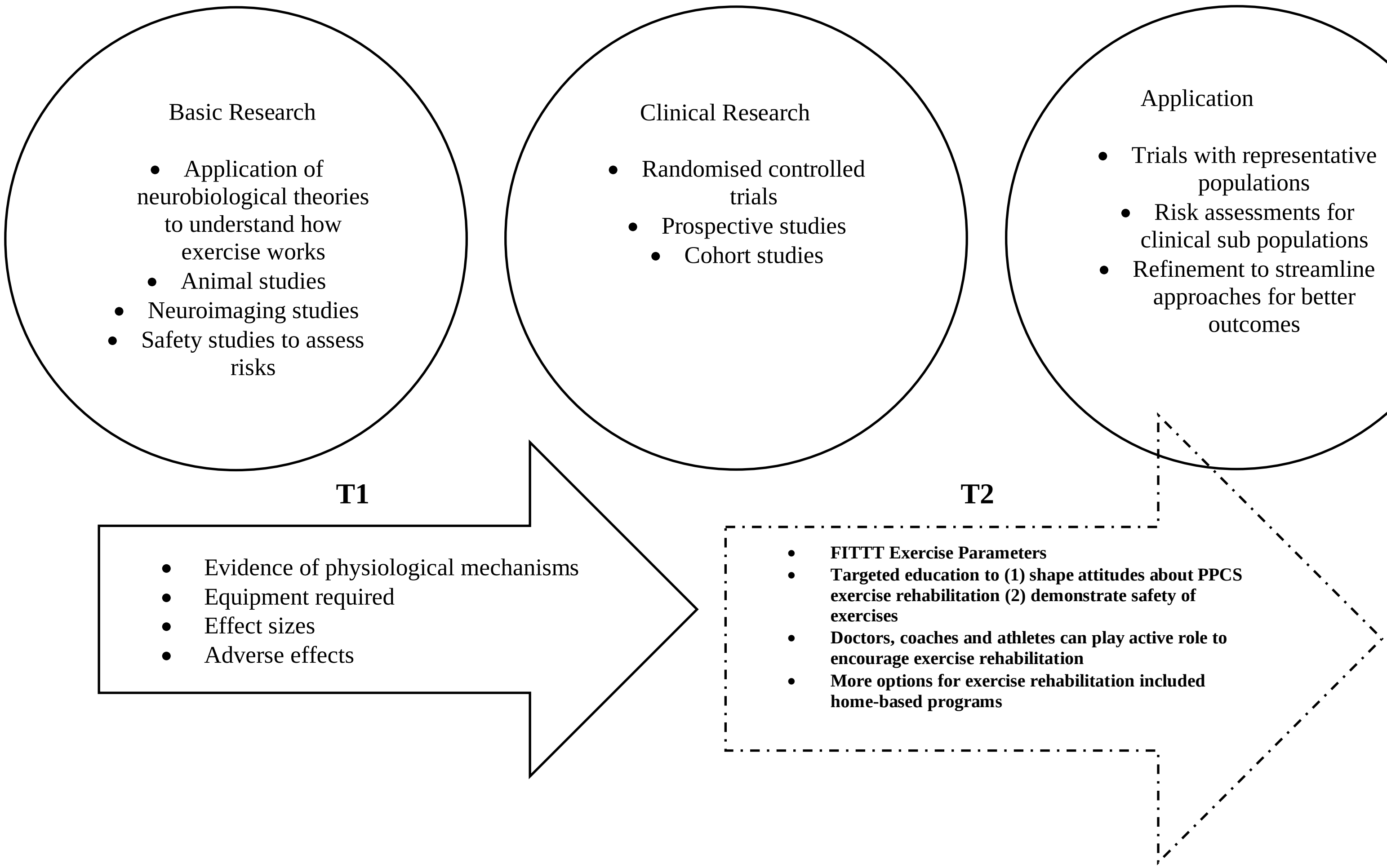
6.3 Theoretical Contributions

The systematic review in this thesis adopted a common exercise framework to define exercise parameters for rehabilitation. While the use of the FITTT framework was guided by exercise (Winters-Stone et al., 2014) and concussion literature (Lawrence et al., 2018), the use of such a structured framework introduces a wider range of possibilities for further research and application in similar areas. The use of a standard and consistent framework is aligned to calls for more congruency in general concussion research (Broglio et al., 2018; Hicks et al., 2013). Adopting a clear and simple set of exercise parameters that can be recalled easily with an acronym (i.e., FITTT) allows for a common language across research and practice settings. By minimising the use of any technical jargon from exercise literature, the framework can also be more accessible to the wider community. Ultimately, it is expected that the use of this exercise framework, if adopted in research and thereafter in practice, will support a stronger body of evidence to emerge than is currently the case for exercise for PPCS.

Next, the theory of planned behaviour is a widely applied theory to understand various types of health behaviour and behaviour modification. While there are criticisms about the theory not giving enough attention to other peripheral factors such as socio-economic status or culture (Sniehotta et al., 2014), proponents of the theory assert that its sufficiency principle accounts for these factors within its existing constructs (Ajzen, 2015). Further, it provided an empirical and established framework to not just identify sociocognitive factors, but also to further research by targeting specific constructs to improve behaviour. Within a PPCS context, this was the first known research to apply the TPB to understand exercise rehabilitation decisions. It is expected that this will guide future attempts to apply this theory or other health behaviour theories to better understand and improve PPCS rehabilitation. The application of this theory by Kroshus and colleagues (Kroshus, Baugh, et al., 2014) to the concussion reporting literature has been widely applauded from the perspective that theory-informed approaches to understand and address nondisclosure issues have been largely ignored. The same might be said of this application of the TPB to concussion rehabilitation; by bringing a theory informed approach to this problem, this thesis demonstrates the value that such approaches can have in advancing the field.

Figure 6. 1

Knowledge Translation Model with Key Findings from this Research Program



Note. Adapted from Martin (2007). T1 = First phase of knowledge translation, T2= Second phase of knowledge translation

6.4 Practical Applications

This section will present practical applications from the key findings in this research program. A key step in addressing knowledge translation gaps is to describe research findings in actionable and practical ways (Lean et al., 2008; Rubio et al., 2010). To achieve this, the following sections will describe the recommendation of exercise rehabilitation and delivery of education by integrating current findings and appropriate literature.

6.4.1 Recommendations for Future Exercise Rehabilitation Studies

The exercise parameters (i.e., FITTT) identified in this thesis were based on studies on athletes. Given that a key intent of this research was to bring evidence-based findings to the wider community, if applicable, it is recommended that a conservative interpretation of the parameters is used as a reference point when prescribing exercise for non-athletes or those who may lack prior conditioning. This approach also allows a moderated approach that provides more latitude for calibration to suit different age groups and fitness levels. As noted, further studies using the recommended exercise parameters will be required before it can be applicable to the wider community.

Frequency of Exercise

First, the review in study 1 found that some support for exercising for a minimum of 4 days to offer some benefits towards PPCS recovery (i.e., frequency). The minimum duration of each activity that provided positive effects were bouts of exercising at 10-15 minutes. Commencing exercise rehabilitation for PPCS in this way might be ideal to maintain exercise participation and facilitate gradual conditioning, especially in non-athletes. Recent evidence supports that multiple sessions of exercise that are 10 minutes or less and accumulated to meet daily recommendations can offer similar benefits as one prolonged single exercise session (Murphy et al., 2019; Yang, 2019). Such customisations can be explored to make the PPCS exercise rehabilitation offering less intense and more time efficient to improve implementation in the wider community. Given the findings from Study 3, especially the view of prospective program users about their preferred session duration, this suggestion seems feasible.

Intensity of Exercise

It is common to use HR measures to assess whether PPCS exercise is attaining the required goal. Given the supposed pathophysiology of concussion and the onset of PPCS, it has been established that increases in cardiovascular activity is needed to reap the potential benefits of exercise. The review found that the minimum HR for activity to yield benefits for PPCS in this study was 50% HR of the sub-symptom threshold. The sub-symptom threshold is a hallmark of PPCS exercise rehabilitation, and the threshold should be established clearly under supervised conditions. Healthcare practitioners will need to provide detailed guidelines on cessation rules upon the onset of symptoms as well as a plan for progression of intensity. Once the person is comfortable to contain exercise without supervision, subsequent sessions could be carried out at home with support from family members and regular check-ins with healthcare providers. With HR measures being readily available to most people in many developed countries (e.g., Fitbit, Apple Watch), PPCS patients can easily monitor and maintain exercise at the required intensity. There is support for such approaches as evident from Chrisman et al. (2021) who found a rehabilitative exercise program for PPCS to be feasible when delivered via telehealth. Participants in this study reported to enjoy the home-based exercise that minimised a need for in-person consultations and the use of wearable fitness monitors. Using such smart devices can also facilitate exchange of data with medical professionals to monitor progress.

Time of Overall Program (Duration)

The findings from study 1 suggest that exercise programs need to last for at least one month for positive outcomes on PPCS. To minimise cost and maintain the efficiency of PPCS exercise rehabilitation, a minimum program duration of 4 weeks is recommended with an option for patients who recover earlier to cease participation in a prescribed program. For those who are slow-to-recover after 4 weeks, further evaluation of symptoms can determine continuation in exercise rehabilitation or the need for intervention from other disciplines (e.g., psychological therapy, medication). Adopting an "as necessary" approach will be more appealing to people who have other commitments and may not be able to participate in exercise rehabilitation for prolonged durations. As already mentioned, study 3 showed that timeline considerations are important for user acceptance. This approach also saves resources for both healthcare providers and patients. A set of exercise recommendations can be provided to people who may be keen to continue maintaining it after the rehabilitation.

Type of Program

In the dominant paradigm for exercise for PPCS (Leddy et al., 2010), treadmill exercise is typically used to establish thresholds and monitor symptom exacerbation safely. For those at risk for falls, stationary bikes have been used. Given that vestibular problems can be a common effect of concussion, such options are important for safety reasons. More recent studies have been less restrictive by allowing participants more choices in their activities (Chrisman et al., 2019; Leddy, Haider, Ellis, et al., 2019) as this has shown to better engage and improve retention in exercise programs (Wulf et al., 2014). While the use of traditional approaches such treadmills may still be important for initial assessment of the sub-symptom threshold and other safety risks, allowing participants to continue exercising in any preferred modality as long as prescribed recommendations were met could be ideal. This choice should not be completely unrestricted; contact sport participation, for example, is not advised until medically cleared.

Time Elapsed Since Injury

This research found moderate support for exercise rehabilitation to be effective for PCS in individuals both in the acute (< 28 days) and prolonged stages (>28 days). While this finding fuels optimism for the potential of exercise rehabilitation after a concussion, it must be noted that most of the participants in the reviewed studies were adolescents, and thus a commonly reported cut-off of 28 days for this population was used. Current guidelines suggest that adults who present with symptoms beyond 10-14 days could be experiencing persistent symptoms. As such, it could be premature to generalise the positive effect of exercise to the wider community and for all stages post-concussion. The sports related concussion literature recommends at least 24-48 hours of rest after an injury in most cases, and this could be strictly applicable for conditioned athletes.

The fact that five of the eight reviewed studies in study 1 focused on studying the benefits of subthreshold exercise in the acute stage in adolescents (<28 days) could be indicative of a shift in the field. This may offer some insights regarding the safety and suitability for exercise to commence relatively soon after an injury, especially when initiated and monitored by trained professionals (i.e., athletic trainers, exercise physiologists). To summarise, it is paramount for further studies to explore the optimal period for exercise commencement after a concussion in greater detail and thorough assessments by healthcare professionals should always precede any exercise recommendations.

6.5 Feasibility and Barriers in Exercise Rehabilitation

An important part of this research program was to identify factors that can increase engagement in PPCS exercise rehabilitation as well as the potential barriers that can be minimised. Along with designing exercise rehabilitation around evidence-based practices, the findings from this study suggest that if PPCS exercise programs are to be adopted, consideration must be given to their cost and accessibility in terms of transportation. More than 80% of participants highlighted preferences for individually calibrated and supervised exercise programs, getting personalised health and fitness information, and a combination of aerobic and resistant exercises. Unfortunately, such supervised exercise programs with personalised features may not come cheap. Exercise physiologists or other trained personnel may be required to determine and calibrate exercise programs according to individual fitness levels and requirements. One way to strike a balance with this conundrum is to use research to convince governments and funding providers that the return of investment in subsiding such exercise programs could be worthwhile using incidence rates of PPCS and the economic burden reduced by enrolment into such programs. As part of using funds efficiently, it can also be highlighted that such a structured program may only be required in the initial conditioning stages and exercise can be self-driven and done without any cost once the patient is conditioned. Progressing from closely monitored lab-based to home-based programs once it is safe to do so can allow family members to monitor the patient, maintain good participation rates, and ultimately reduce the implementation costs for such programs. Thus, a formal cost-effectiveness evaluation that juxtaposes the costs of tailored exercise programs with the costs of healthcare usage due to PPCS is recommended. This can help to justify subsidies for a community-accessible exercise program for PPCS, compared to usual care.

Participants in this study identified a lack of time and work commitments as barriers to exercising. While these are commonly cited reasons for poor participation in exercise rehabilitation (Ebben & Brudzynski, 2008; Tappe et al., 1989), the ability to adapt the recommended set of exercise parameters for home-based exercises after an initial period of monitoring could be useful to address this issue. For example, it is now much easier to carry out prescribed exercising at home using personal HR monitors. If necessary, collaboration platforms such as Zoom can be used to monitor exercise progress, calibrate individualised exercises, and mete out health advice and support as noted in a similar program by Chrisman et al (2021). The proliferation of video-guided exercises (e.g., Apple Fitness +) are also other home-based alternatives that can be considered after consultation with a medical professional. Some of these programs contain well-structured activities and embed progressive increments to intensity within the program, making it a good option for this context.

6.6 Other Considerations

PPCS has been established as a complex and unpredictable condition throughout this thesis. The onset of symptoms in various stages post-concussion can be triggered by a wide range of physical and psychological factors identified in Chapter 2. The reason why some people do not develop any symptoms after a concussion while others do still eludes researchers. Given the level of heterogeneity in symptom presentation, this research program does not propose that exercise supplants all other treatment modalities that could be instrumental for recovery. Rather, exercise as a pan-domain rehabilitation option, is expected to complement any other specific treatment modality that is ideally recommended by a multi-disciplinary team of health professionals. As such, a careful assessment of peri-injury individual and psychological factors may result in exercise to be not suitable or to be more appropriate at a much later stage of recovery. For example, the injured person could require psychological help to address any trauma resulting from the injury before other considerations. Such decisions may better serve the interest of the patient, be a more resource efficient approach and in keeping with the ultimate goal of rehabilitation which is clinical recovery of the patient.

6.7 Delivery of Education

The findings in this study revealed that common knowledge gaps and misinformed attitudes, as reported in previous studies (Feiss et al., 2020; Waltzman & Daugherty, 2018; Yeo et al., 2020), may exist in Australian communities. Future education efforts for the general community and athletes can be improved by highlighting some of these misunderstood issues. Drawing from findings in this research program, common misconceptions such as staying in a dark room or not sleeping needs to be identified and dispelled using evidence-based and credible advice.

As indicated in the knowledge translation literature, education efforts need to be adapted to the needs of the audience (Heath et al., 2012; Martin et al., 2008; Weed, 2016). This suggests a move away from passive delivery of content through lectures or talks to one that uses a combination of platforms such as seminars, internet, and the media for optimal knowledge transfer (Provvidenza & Johnston, 2009). Collaborative practices with doctors, coaches, athletes, and researchers can also ensure that everyone is kept apprised of the latest management advice to minimise and address knowledge gaps among key figures, especially if they may influence rehabilitation. For example, current studies indicate that medical healthcare professionals lack knowledge about rest and exercise rehabilitation for PPCS (Silverberg & Otamendi, 2019). Taken together with findings by Knox et al. (2017) that doctors play a critical role in the recovery journey of patients, targeted seminars for doctors and other healthcare professionals on current management guidelines can make the difference between a patient experiencing prolong symptoms without any respite or being advised to enrol in an exercise rehabilitation program. Training different healthcare professionals such as Emergency Department nurses, doctors, psychologists, and physiotherapists on concussion management can also be an effective strategy that is thorough and minimises fragmentation of medical care.

The findings on the TPB constructs in this study can be used to modify education efforts in more specific ways that leverage the most influential factors in people's *intention* to exercise for PPCS. In this study, it was suggested that positive *attitudes* about exercise rehabilitation did not indicate that people are likely to participate in such programs. While half the battle may be won if people already hold positive beliefs about exercise, education efforts then need to address possible concerns underlying this discrepancy between *attitudes* and *intention*. For example, it may require more dedicated discussion about exercise rehabilitation and how it can be safe for people to take part in after a concussion.

Perceived behavioural control was found to be predictive of *intention* to exercise for PPCS but this was not as strong a predictor as *subjective norms*. While this was mostly a measure of self-confidence in participating in PPCS exercise rehabilitation, it can be challenging to address for non-athletes or people who do not like exercising. The ability to customise exercise programs for different people could be a potential solution. More enjoyable exercise modalities that are considered less mundane but can still achieve desirable effects can be offered as options for those who dislike exercising, improving self-efficacy and PBC in the process. Those who lack the confidence may benefit by commencing exercises at lower intensities and spending more time under supervision before being allowed to exercise at home. The indirect measures of *perceived behavioural control* also suggest common control issues related to not being able to find time or the motivation for exercise. Customisable exercise options can be considered for such groups to empower them with the choice to exercise at their own time and preferred modality.

Finally, *subjective norms* were the strongest predictor of exercise *intention* for PPCS, suggesting that education efforts that come through important referent groups may be instrumental to improve participation in PPCS exercise rehabilitation. Given the powerful role of the media, popular sports personnel who were important referent groups, as identified in this study, can collaborate with media companies to act as ambassadors in public promotion and advertising campaigns for PPCS exercise rehabilitation. They can share personal experiences of using exercise rehabilitation or demonstrate the potential of such approaches to help progress towards return to play and normal activities. Another important referent group in this study were doctors. This mirrors previous findings that medical professionals play a critical role in PPCS rehabilitation for both athletes and non-athletes (Knox et al., 2017; Provvidenza & Johnston, 2009). In clinical contexts, proper training for healthcare providers (e.g., doctors, physiotherapists) can enable them to be confidently promote exercise rehabilitation and actively refer suitable patients to take it up. The power of *subjective norms* can also be harnessed through peer support in exercising. People with the experience of exercise rehabilitation can continue to share their experiences with significant others to pass on the message about the potential benefits of such evidence-based practices.

6.8 Strength, Limitations and Future Directions

6.8.1 Strengths

A strength of this research program was its novelty. While other reviews have attempted to review exercise parameters for PPCS rehabilitation, there has been none, to the knowledge of the author, that, have drawn from findings based on high quality randomised controlled trials that only assess the effectiveness of unimodal exercise for PPCS. Granted, this can be challenging considering that most studies in this area have examined the use of multimodal approaches that are more pragmatic for PPCS. However, exploring studies that compared exercise with a control group provided a potentially unconfounded set of exercise parameters to work with and recommend for future research.

The use of clear and widely established theoretical frameworks in this research program was also noteworthy. Other concussion studies have used the theory of planned behaviour to understand reporting behaviour and the impact of education efforts, but none have applied this theory to understand decisions towards PPCS rehabilitation. Taken together with the use of a structured and simple exercise framework (i.e., FITTT), the findings from this research are expected to be easier to replicate and apply in multiple settings.

Finally, the literature is replete with concussion studies on injury definitions, complexity of symptoms, and reporting of injuries, but this study placed emphasis on a specific rehabilitation option and how this can be made available to the wider community using a simple and accessible structure. In doing this, this research program attempted to bridge knowledge translation gaps by drawing from literature that is commonly carried out in athletes and adolescents and adapt the findings to an often-understudied non-athlete group with similar risks to PPCS (Haider et al., 2020; Thomas et al., 2020b).

6.8.2 Limitations

While the limitations of each study are addressed in the respective chapters, this section will address the limitations of the overall research program. First, the study focussed specifically on exercise rehabilitation for PPCS and omitted several studies from the literature that incorporated exercise as part of a multimodal rehabilitation program. While it can be argued that the exercise parameters identified in this research program are similar to those already used in most multimodal programs, there is a possibility that this research program omitted some useful exercise parameters as a result of the stringent screening process. Exploration of exercise as part of other multimodal programs was beyond the scope of this study. Taking on board the idea that exercise could be a pan-rehabilitation approach, a study that compares exercise only versus multimodal programs, is very much needed.

Second, while the use of the theory of planned behaviour in this study allowed a structured exploration of sociocognitive factors underlying *intention* to participate in PPCS exercise rehabilitation, some important considerations could have been overlooked. For example, Cusimano et al. (2017) found factors such as language (e.g., non-English speaking background), ethnicity, gender, and socio-economic background to affect concussion education and knowledge. These factors were not explored in this study.

Finally, this study used a largely non-clinical population to make inferences about the decisions that a clinical population will need to make. While it can be argued that vignette studies in concussion literature have used similar approaches and made significant contributions to concussion diagnosis and injury management, there is a possibility that people might think and act very differently after an actual concussion. The third study in this research program included a small proportion that reported a history of injury, but the sample size was too small for inclusion in sub-group analysis. Nevertheless, the risk of a concussion and PPCS applies to everyone and there is some value in exploring knowledge and rehabilitation in the wider community as done by this research program.

6.8.3 Future Directions

This research program identified and recommended a set of exercise parameters based on evidence-based studies among athletes. While it was highlighted that a more conservative approach is taken for non-athletes when applying some of the exercise recommendations, there is scope to examine the effectiveness of some of the recommended parameters in different population groups. Being the gold standard for evidence-based rehabilitation, randomised controlled trials can be used to determine optimal and more efficient exercise parameters for older people or children. These groups, especially older adults, are typically neglected in PPCS research, and yet, falls are a significant cause of mTBI in this age group.

Future exercise studies can also compare the effectiveness of exercise studies on its own or as part of other multi-disciplinary rehabilitation. As noted previously, the parameters recommended in this study have not been tested in non-athletic populations and feasibility studies can help determine the best set of parameters or further modifications that may be necessary for different sub-populations. As there is an increasing acceptance for cohort studies and non-randomised trials to provide evidence for rehabilitation (Lean et al., 2008; Mueller et al., 2018), future exploration of such studies can provide insights into other possibilities for exercise rehabilitation that offer beneficial outcomes for PPCS.

The application of other health behaviour models or an integrated approach that could account for more variability in *intention* to exercise can be explored in the PPCS rehabilitation context. Such theories can be useful to identify factors that may be overlooked when using one theory, such as the TPB. There have been calls for different theoretical explanations to explain how people change behaviour or how reliably *intention* can predict behaviour (Sniehotta et al., 2014). A better understanding of such factors around rehabilitation decisions can be instrumental to bridge the chasm between PPCS rehabilitation research and application.

6.9 Summary and Conclusion

This research program aimed to reduce PPCS in the population by investigating existing knowledge translation gaps in rehabilitation research. While exercise is a promising pan-domain option for PPCS, a lack of clear guidelines, gaps in knowledge about concussion rehabilitation and personal factors influencing such decisions were offered as potential reasons for the lag in adopting PPCS exercise rehabilitation for the wider community. Using three studies, this thesis (1) established a clear set of evidence-based exercise guidelines for adoption in research and clinical contexts for the wider community; (2) identified common gaps in concussion knowledge and a lack of awareness about evidence-based rehabilitation in an Australian community sample, and (3) clarified personal factors that can influence the decision to take part in PPCS exercise rehabilitation.

The research program recommended that the conservative ends of the identified exercise parameters be adopted for research among the general community. Future education programs for concussion should consider the need to have more specific information addressing common knowledge gaps. Evidence on the effectiveness of exercise rehabilitation and encouragement to participate in such programs may be better received if delivered by highly regarded referent groups such as doctors and athletes. Future research can consider a wider inclusion of studies with different designs to identify a greater range of exercise parameters, compare the effectiveness of different exercise parameters and explore other health behaviour theories to better understand rehabilitative decisions in a PPCS context.

This thesis started with an account of Loris Karius, the Liverpool goalkeeper who suffered post-concussion symptoms and whose disorientation and misjudgement led to the defeat of his team. It was also brought to attention that concussion or sub-concussions may be a weekly affair in some sports. Concussion and post-concussion symptoms will continue to be a problem in contact sports and many other walks of life, including non-sports related injuries. The “miserable minority” often claimed to suffer persistent PPCS could include grandparents, family, friends, and children. It is important that research efforts to raise awareness of concussion and effective rehabilitation options for everyone in the wider community continues. Knowing about an effective rehabilitation option such as exercise and recommending it to someone with PPCS could help them recovery from this very “miserable” condition.

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Appendix A – Ethical Clearance and Risk Assessment

<u>Ethics Approval Email – 1900000328</u>

From: Research Ethics (HUMAN) | humanethics@qut.edu.au

To: Karen Sullivan | karen.sullivan@qut.edu.au, Kannan Singaravelu Jaganathan | k.singaravelujaganathan@hdr.qut.edu.au, Ms Sally Kinmond | sally.kinmond@connect.qut.edu.au

Cc: Human Ethics Advisory Team | humanethics@qut.edu.au

Dear Prof Karen Sullivan

Approval #: 1900000328 End Date: 17/09/2020 Project Title: Community knowledge and attitudes about concussion: A survey study with an educational intervention

The variation to this research project submitted was approved by the Chair or delegate, QUT Human Research Ethics Committee (UHREC).

Approval has been provided for:

< Extension: extension of data collection phase to May 2020; the project end date is currently Sept 2020.

< Incentive: prize draw expiration; nil replacement.

Please note that all requirements of the original ethical approval for this project still apply.

Please also note:

< All health, safety and environment risks relating to this variation must be appropriately addressed via and risk assessment where appropriate (please see qutvirtual4.qut.edu.au/group/staff/people/health-and-safety/hazard-m

anagement/risk-management) and your local HSE contacts (please see qutvirtual4.qut.edu.au/group/staff/people/health-and-safety/hse-comm unity/local-hse-contacts).

< If this variation will introduce any additional perceived or actual conflicts of interest please follow the appropriate procedures at www.orei.qut.edu.au/integrity/coi.jsp.

Should you have any queries about the consideration of your project, please contact the Research Ethics Advisory Team on 07 3138 5123 or email humanethics@qut.edu.au.

We wish you every continued success in your research.

Research Ethics Advisory Team, Office of Research Ethics & Integrity on behalf of Chair, UHREC Level 4 | 88 Musk Avenue | Kelvin Grove +61 7 3138 5123 | humanethics@qut.edu.au www.orei.qut.edu.au

The UHREC is constituted and operates in accordance with the National Statement on Ethical Conduct in Human Research (2007) and registered by the National Health and Medical Research Council (# EC00171).

<u>Ethics Approval Email – 2000000355</u>

From: Research Ethics (HUMAN) | humanethics@qut.edu.au

To: Karen Sullivan | karen.sullivan@qut.edu.au, Kannan Singaravelu Jaganathan | k.singaravelujaganathan@hdr.qut.edu.au

Cc: Human Ethics Advisory Team | humanethics@qut.edu.au

Dear Prof Karen Sullivan

Approval #: 2000000355 End Date: 22/06/2022 Project Title: Understanding the factors affecting intentions to exercise after a concussion

The variation to this research project submitted was approved by the Chair or delegate, QUT Human Research Ethics Committee (UHREC).

Approval has been provided for:

< Methods: additional questions to assess indirectly, perceived behaviour control.

Please note that all requirements of the original ethical approval for this project still apply.

Please also note:

< All health, safety and environment risks relating to this variation must be appropriately addressed via and risk assessment where appropriate (please see qutvirtual4.qut.edu.au/group/staff/people/health-and-safety/hazard-m anagement/risk-management) and your local HSE contacts (please see qutvirtual4.qut.edu.au/group/staff/people/health-and-safety/hse-comm unity/local-hse-contacts).

< If this variation will introduce any additional perceived or actual conflicts of interest please follow the appropriate procedures at www.orei.qut.edu.au/integrity/coi.jsp.

Should you have any queries about the consideration of your project, please contact the Research Ethics Advisory Team on 07 3138 5123 or email humanethics@qut.edu.au.

We wish you every continued success in your research.

Monday, 29 Jun 2020, 12:50 PM Research Ethics Advisory Team, Office of Research Ethics & Integrity on behalf of Chair, UHREC Level 4 | 88 Musk Avenue | Kelvin Grove +61 7 3138 5123 | humanethics@qut.edu.au www.orei.qut.edu.au

The UHREC is constituted and operates in accordance with the National Statement on Ethical Conduct in Human Research (2007) and registered by the National Health and Medical Research Council (# EC00171).

Approval of risk assessment for study

Name	Online survey of concussion knowledge.xml
Workflow Status	Approved
Hazard Categories	Manual Handling / Ergonomic Hazards
Modification Agent	Workflow
Previously Modified	
Archive Button	
Approval	
Approval History	No existing entries.
Approval Status	Approved

Content Type: Form
Version: 1.0
Created at 21/08/2019 3:19 PM by Karen Sullivan
Last modified at 22/08/2019 3:02 PM by Karen Sullivan

Close

Appendix B – PROSPERO Records

27/1/22, 3:52 pm

NIHR | National Institute for Health Research

PROSPERO
International prospective register of systematic reviews

A systematic review of exercise characteristics to improve persistent post-concussion symptoms

Karen Sullivan, Kannan Singaravelu

Citation

Karen Sullivan, Kannan Singaravelu. A systematic review of exercise characteristics to improve persistent post-concussion symptoms. PROSPERO 2016 CRD42016049828 Available from: https://www.crd.york.ac.uk/prospero/display_record.php?ID=CRD42016049828

Review question

What are specific parameters of exercise interventions that improve persistent symptoms after a mild traumatic brain injury? (e.g. dose, duration, frequency, time after injury)

Searches

The search terms were searched as a combination of subject headings and keywords in the following databases; CINAHL (EBSCOhost), PsycINFO (EBSCOhost), MEDLINE (Ovid), Embase (Embase.com), SPORTDiscus (EBSCOhost), AMED - Allied and Complementary Medicine Database (EBSCOhost) and Cochrane Reviews (Cochrane Library). In 2014, the term "posttraumatic symptoms" was recommended as an alternative term for post-concussion syndrome (Cassidy et al., 2014, p. s149). This term (and its synonyms) was searched from 2013 onwards.
To find and include both negative results and the most up to date research, theses and clinical trial registries were searched using; ProQuest Dissertation & Theses Global database, Cochrane Central Register of Controlled Trials (Cochrane Library), ClinicalTrials.gov, UK Clinical Trials, Australian New Zealand Clinical Trials Registry, EU Clinical Trials Register and the WHO International Clinical Trials. The searches were run 6-23 September 2019.
Manual searching will be performed on reference lists from relevant doctoral dissertations, the prior systematic reviews, and the screened studies.

Types of study to be included

RCTs, clinical trials, meta-analyses, systematic reviews

Condition or domain being studied

Mild traumatic brain injury

Participants/population

Human, adults, mild traumatic brain injury

Intervention(s), exposure(s)

Non-pharmacological physical-based interventions to improve post-concussion symptoms

Comparator(s)/control

Non-exposed control group

Main outcome(s)

Post-concussion symptoms

Measures of effect

Not applicable.

Additional outcome(s)

Well-being, quality of life, return to work/sports

Measures of effect

Not applicable.

Data extraction (selection and coding)

A member of the review team will carry out the keyword searches in the databases and remove duplicates. Two independent reviewers will then search the title and abstracts of the remaining citations. Disagreements in inclusion will be resolved through discussions and when not possible, a third reviewer will be consulted. For included citations, the full-text articles will be retrieved and read to determine eligibility based on the inclusion/exclusion criteria. Agreement of study eligibility will be analysed using the kappa statistic and 95% confidence interval. The process will be recorded using PRISMA guidelines.

Two independent reviewers will extract data reported in eligible studies. When information is unavailable, the author will be contacted for details. Disagreements in data inclusion will be resolved through discussions and, when not possible, a third reviewer will be consulted. Data for intervention measures (e.g. stipulated parameters for the exercise intervention) and primary outcome measures (e.g. post-concussion symptoms) will be extracted. If meta-analysis is possible, the relevant data (e.g. effect sizes, confidence intervals) will be analysed and reported.

Risk of bias (quality) assessment

Risk of bias will be assessed. The method is to be determined. Studies with high risk of bias will be excluded from the interpretation.

Strategy for data synthesis

A narrative synthesis technique will be used to evaluate the selected literature. Measures of interest will be recorded and where possible included for analysis after an assessment based on the risk of bias analysis and relevance for inclusion.

Analysis of subgroups or subsets

None planned.

Contact details for further information

Dr Karen Sullivan
karen.sullivan@qut.edu.au

Organisational affiliation of the review

QUT

Review team members and their organisational affiliations

Dr Karen Sullivan. QUT
Mr Kannan Singaravelu. QUT

Type and method of review

Narrative synthesis, Systematic review

Anticipated or actual start date

06 September 2019

Anticipated completion date

31 December 2020

Funding sources/sponsors

None

Conflicts of interest

None known

Language

English

Country

Australia

Stage of review

Review Ongoing

Subject index terms status

Subject indexing assigned by CRD

Subject index terms

Brain Injuries; Exercise; Homeostasis; Humans; Rest

Date of registration in PROSPERO

19 October 2016

Date of first submission

13 February 2020

Stage of review at time of this submission

Stage	Started	Completed
Preliminary searches	Yes	No
Piloting of the study selection process	Yes	No
Formal screening of search results against eligibility criteria	No	No
Data extraction	No	No
Risk of bias (quality) assessment	No	No
Data analysis	No	No

Revision note

We revisited the area of focus for this systematic review with a careful consideration of the gaps in the literature and the relevance for clinical applicability.

The record owner confirms that the information they have supplied for this submission is accurate and complete and they understand that deliberate provision of inaccurate information or omission of data may be construed as scientific misconduct.

The record owner confirms that they will update the status of the review when it is completed and will add publication details in due course.

Versions

19 October 2016
22 October 2020

PROSPERO
This information has been provided by the named contact for this review. CRD has accepted this information in good faith and registered the review in PROSPERO. The registrant confirms that the information supplied for this submission is accurate and complete. CRD bears no responsibility or liability for the content of this registration record, any associated files or external websites.

Appendix C – Systematic review search strategy

Keywords	“mTBI”, “concussion”, “post-concussion”, “head-injury”, “minor head injury”, “physical activity”, “exercise”
Search syntax	“mTBI” AND “exercise” OR “physical activity” OR “rehabilitation” OR “intervention” OR “dance therapy” OR “exercise therapy” OR “endurance” OR “gymnastics” OR “cycl*” OR “jogging” OR “kinesiotherapy” OR “mind body therapy” OR “neurophysiotherapy” OR “treadmill exercise” OR “running” OR “exertion” OR “physical training” OR “pilates” OR “strength training” OR “resistance training” OR “sports” OR “weight lifting” OR “walk*” OR “yoga” “concuss*” AND “exercise” OR “physical activity” OR “rehabilitation” OR “intervention” OR “dance therapy” OR “exercise therapy” OR “endurance” OR “gymnastics” OR “cycl*” OR “jogging” OR “kinesiotherapy” OR “mind body therapy” OR “neurophysiotherapy” OR “treadmill exercise” OR “running” OR “exertion” OR “physical training” OR “pilates” OR “strength training” OR “resistance training” OR “sports” OR “weight lifting” OR “walk*” OR “yoga” “post-concuss*” AND “exercise” OR “physical activity” OR “rehabilitation” OR “intervention” OR “dance therapy” OR “exercise therapy” OR “endurance” OR “gymnastics” OR “cycl*” OR “jogging” OR “kinesiotherapy” OR “mind body therapy” OR “neurophysiotherapy” OR “treadmill exercise” OR “running” OR “exertion” OR “physical training” OR “pilates” OR “strength training” OR “resistance training” OR “sports” OR “weight lifting” OR “walk*” OR “yoga” “PCS” AND “exercise” OR “physical activity” OR “rehabilitation” OR “intervention” OR “dance therapy” OR “exercise therapy” OR “endurance” OR “gymnastics” OR “cycl*” OR “jogging” OR “kinesiotherapy” OR “mind body therapy” OR “neurophysiotherapy” OR “treadmill exercise” OR “running” OR “exertion” OR “physical training” OR “pilates” OR “strength training” OR “resistance training” OR “sports” OR “weight lifting” OR “walk*” OR “yoga”

	“PPCS” AND “exercise” OR “physical activity” OR “rehabilitation” OR “intervention” OR “dance therapy” OR “exercise therapy” OR “endurance” OR “gymnastics” OR “cycl*” OR “jogging” OR “kinesiotherapy” OR “mind body therapy” OR “neurophysiotherapy” OR “treadmill exercise” OR “running” OR “exertion” OR “physical training” OR “pilates” OR “strength training” OR “resistance training” OR “sports” OR “weight lifting” OR “walk*” OR “yoga”
Databases	CINAHL (EBSCOhost), PsycINFO (EBSCOhost), MEDLINE (Ovid), Embase (Embase.com), SPORTDiscus (EBSCOhost), AMED - Allied and Complementary Medicine Database (EBSCOhost) and Cochrane Reviews (Cochrane Library)
Theses and Clinical Trial registries	ProQuest Dissertation & Theses Global database, Cochrane Central Register of Controlled Trials (Cochrane Library), ClinicalTrials.gov, UK Clinical Trials, Australian New Zealand Clinical Trials Registry, EU Clinical Trials Register and the WHO International Clinical Trials.

Appendix D – Screening sheet for systematic review

Author(s)	Year of Publication	Endnote Record	Title	Abstract	Study Aim	N size	Profile of N (e.g., age, sex, etc)

Screening sheet for systematic review (continued)

Date/duration of data collection	Where was data collected?	How was mTBI/concussion assessed?	Inclusion criteria	Exclusion criteria	Were participants with history of concussion included?	Were patients with co-morbid issues included?	How was post-concussion symptoms assessed?

Screening sheet for systematic review (continued)

Post-concussion symptom measures	Nature of injury (e.g., Sports related, motor vehicle accident)	Timing of exercise intervention after concussion	Type of study (e.g., RCT, cohort study)	What was the exercise intervention?	Was there any rationale provided for the exercise intervention?	Materials used in study (e.g., HR monitor, exercise bikes)	Were there any motivation strategies/incentives?

Screening sheet for systematic review (continued)

Who delivered the intervention? (e.g., exercise physiologist, researcher)	What is the control condition if any? (e.g., stretching, wait-list)	Frequency of exercise prescribed in intervention (e.g., how many sessions per week?)	Duration of each exercise session (e.g., how long was each session?)	Intensity of exercise prescribed per session (e.g., 1RM, HR, perceived exertion)	Length of program (e.g., 8 weeks, number of sessions completed)	Mode of exercise (e.g., treadmill running, stationary bike cycling)	Progressive or fixed exercise protocol

Screening sheet for systematic review (continued)

Was exercise tailored to fitness levels of participants?	Were there cessation rules for exercise?	Was the exercise individual or group-based?	Was the exercise home-based or in a controlled setting?	Were there any non-exercise components as part of the intervention? (e.g., psychological therapy, physiotherapy)	Did participants get a choice of exercise?	Was adherence to intervention assessed?	Was there a record of incidental exercise?

Screening sheet for systematic review (continued)

What was the primary outcome of the study?	What were the secondary outcomes of the study?	Was return to activity or sports measured?	Were any adverse effects reported?	Was there any effect size reported?	Overall findings/conclusion in study	Study limitations	Additional comments

Appendix E – Online survey to assess concussion knowledge, attitudes, and recommendations for rehabilitation

Demographic Questions

In this section, we are interested in finding out some details about you.

What is your age in years? (Please respond using numbers only)

____

What is your gender?

Male
Female
Other
Prefer not to disclose

What is your ethnicity?

Caucasian
Aboriginal or Torres Strait Islander
South Asian
South East Asian
North Asian
African
Pacific Islander
Other (Pls specify):
____

In which state or territory do you reside? If outside of Australia, please specify the country in the text box below:

QLD
NSW
VIC
ACT
TAS
SA
WA
NT
Others (Pls specify):
____

How many years of education have you completed? (Please respond using numbers only):

____

What is the highest qualification you have achieved?

No education
Primary school
High school (no certificate)
High school graduate
Trade/technical/vocational training
University (no degree)
Associate degree
Bachelor's degree
Master's degree
Doctorate degree

What is your current employment status?

Unemployed
Home duties
Casual worker
Part-time worker
Self-employed
Permanent employee

What is your primary occupation?
Manager
Professional
Technician and trade worker
Community and Personal service worker
Clerical and Administrative worker
Sales worker
Machinery Operators and drivers
Labourers
Student
Others:
____

What is your usual gross annual income (before tax)?
$0-$18,200
$18,201-$37,000
$37,001-$90,000
$90,001-$180,000
$180,001 and over

What is your current relationship status?
Single-never married
Married
De-facto
Widowed
Divorced
Separated

Sports Participation

Do you play contact sports?
Yes
No

What type of contact sports do you play?
Australian Rules
Basketball
Boxing
Hockey
Ice Hockey
Marital Arts
Rugby League
Rugby Union
Soccer
Volleyball
Wrestling
Others: ___________

Which one of the following categories best describe the level you play at? (If you play multiple sports at various levels, indicate the highest level that you play one or more sports).

Professional or elite level
State level
Regional level
Recreation

Concussion History and Education

Have you experienced a concussion in the past?
Yes
No

If yes, how many concussions have you experienced in the past?

____

Have you experienced a concussion in the last 6 months?
Yes
No
If yes, when did you have the most recent concussion?
Less than 1 to 2 weeks ago
More than 2 weeks to 4 weeks ago
More than 1 month to 2 months ago
More than 2 months to 4 months ago
More than 4 months to 6 months ago
Have you studied or been taught about concussion?
Yes
No
If yes, how was the concussion education delivered? If you have received education via multiple sources, then please select all appropriate options.
Brochures
Via a coach or trainer
Online (i.e., Youtube)
Formal classroom training
Medical professional
Social media
Smartphone apps
TV ads
Interactive website
Radio ads
Newspaper ads or articles
Other

Treatment and Validation of Injury
Did you seek medical treatment for your concussion?
Yes
No

If yes, were you treated at hospital within 24 hours for your most recent concussion?
Yes
No
Maybe

Did you lose consciousness when you had the concussion?
Yes
No
Maybe

Do you have a clear memory of the events immediately before and after the most recent concussion?

Yes
No
Maybe

Are you still receiving any form of treatment for your most recent concussion?
Yes
No

Can you recall what caused your concussion(s)?
Sports and recreation
Motor vehicle accident
Workplace accident

Assault
Fall
Cannot recall
Ohers: (Pls specify):
____

Can you recall if you were advised by at least one healthcare professional to rest for more than 2 days after your most recent concussion?

Yes
No
Maybe

Do you feel that you have recovered a 100% since your most recent concussion? (On a scale of 0-100)

0 ---100
Not recovered at all *Complete recovery*

If you think you have persistent symptoms from the concussion that should have cleared up by now, how would you seek treatment? (Please select the most likely option)

See a doctor
Go to a hospital emergency department
Go to a concussion clinic
Consult a psychologist
Search the internet for help
Do nothing
Others (Pls specify:)
____

Have you resumed normal activities (i.e., return to work/sports/school) since your most recent concussion?

Yes
No

For your most recent concussion, did you or are you in the midst of seeking compensation (e.g., insurance claims, work compensation)?

Yes
No

For your most recent concussion, were you or are you currently involved in any litigation/investigation (e.g., court hearing, police investigation)?

Yes
No

Do you have a current psychiatric diagnosis (e.g., anxiety disorder, depression, bipolar, schizophrenia)?

Yes
No

Do you have any neurological disorders/conditions (e.g., brain injury, stroke, Parkinson's disease, Alzheimer's disease)?

Yes
No

Rosenbaum Concussion Knowledge and Attitudes Survey (RoCKAS)

Section 1:

Directions: Please read the following statements and select TRUE or FALSE for each question

1.	There is a possible risk of death if a second concussion occurs before the first one has healed.	TRUE	FALSE
2.	Running everyday does little to improve cardiovascular health.	TRUE	FALSE
3.	People who have had one concussion are more likely to have another concussion.	TRUE	FALSE
4.	Cleats (also known as sprigs, tags, studs, and stops) are used to help athletes' feet grip the playing surface	TRUE	FALSE
5.	In order to be diagnosed with a concussion, you have to be knocked out.	TRUE	FALSE
6.	A concussion can only occur if there is a direct hit to the head.	TRUE	FALSE
7.	Being knocked unconscious always causes permanent damage to the brain.	TRUE	FALSE
8.	Symptoms of a concussion can last for several weeks.	TRUE	FALSE
9.	Sometimes a second concussion can help a person remember things that were forgotten after the first concussion.	TRUE	FALSE
10.	Weightlifting helps to tone and/or build muscle.	TRUE	FALSE
11.	After a concussion occurs, brain imaging (e.g., CAT Scan, MRI, X-Ray, etc.) typically shows visible physical damage (e.g., bruise, blood clot) to the brain.	TRUE	FALSE
12.	If you receive one concussion and you have never had a concussion before, you will become less intelligent.	TRUE	FALSE
13.	After 10 days, symptoms of a concussion are usually completely gone.	TRUE	FALSE
14.	After a concussion, people can forget who they are and not recognize others but be perfect in every other way.	TRUE	FALSE
15.	The colour of a player's rugby shirt has an effect on whether the team wins.	TRUE	FALSE
16.	Concussions can sometimes lead to emotional disruptions.	TRUE	FALSE
17.	An athlete who gets knocked out after getting a concussion is experiencing a coma.	TRUE	FALSE
18.	There is rarely a risk to long-term health and well-being from multiple concussions.	TRUE	FALSE

Section 2:

Directions: Please read each of the following scenarios and circle TRUE or FALSE for each question that follows the scenarios.

Scenario 1:
While playing in a game, Player Q and Player X collide with each other and each suffers a concussion. Player Q has never had a concussion in the past. Player X has had 4 concussions in the past.

1	It is likely that Player Q's concussion will affect his long-term health and well-being.	TRUE	FALSE
2	It is likely that Player X's concussion will affect his long-term health and well-being.	TRUE	FALSE

Scenario 2:

Player F suffered a concussion in a game. She continued to play in the same game despite the fact that she continued to feel the effects of the concussion.

3	Even though Player F is still experiencing the effects of the concussion, her performance will be the same as it would be had she not suffered a concussion.	TRUE	FALSE

Section 3:

Directions: For each question, select the number that best describes how you feel about each statement.

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

1	I would continue playing a sport while also having a headache that resulted from a minor concussion.	1	2	3	4	5
2	I feel that coaches need to be extremely cautious when determining whether an athlete should return to play.	1	2	3	4	5
3	I feel that mouthguards protect teeth from being damaged or knocked out.	1	2	3	4	5
4	I feel that professional athletes are more skilled at their sport than other high school athletes.	1	2	3	4	5
5	I feel that concussions are less important than other injuries.	1	2	3	4	5
6	I feel that an athlete has a responsibility to return to a game even if it means playing while still experiencing symptoms of a concussion.	1	2	3	4	5
7	I feel that an athlete who is knocked unconscious should be taken to the emergency room.	1	2	3	4	5
8	I feel that most high-school athletes will play professional sports in the future.	1	2	3	4	5

Section 4:

Directions: For each question, read the scenarios and select the number that best describes your view. (For the questions that ask what most athletes feel, base your answers on how you think MOST athletes would feel.)

		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
	Scenario 1: *Player R suffers a concussion during a game. Coach A decides to keep Player R out of the game. Player R's team loses the game.*					
1	I feel that Coach A made the right decision to keep Player R out of the game.	1	2	3	4	5
2	Most athletes would feel that Coach A made the right decision to keep Player R out of the game.	1	2	3	4	5
	Scenario 2: *Athlete M suffered a concussion during the first game of the season. Athlete O suffered a concussion of the same severity during the semi-final playoff game. Both athletes had persisting symptoms.*					
3	I feel that Athlete M should have returned to play during the first game of the season. 4 5 6	1	2	3	4	5
4	Most athletes would feel that Athlete M should have returned to play during the first game of the season.	1	2	3	4	5
5	I feel that Athlete O should have returned to play during the semi-final playoff game.	1	2	3	4	5
6	Most athletes feel that Athlete O should have returned to play during the semifinal playoff game.	1	2	3	4	5
	Scenario 3: *Athlete R suffered a concussion. Athlete R's team has an athletic trainer on the staff.*					

7	I feel that the athletic trainer, rather than Athlete R, should make the decision about returning Athlete R to play.	1	2	3	4	5
8	Most athletes would feel that the athletic trainer, rather than Athlete R, should make the decision about returning Athlete R to play.	1	2	3	4	5
	Scenario 4: *Athlete H suffered a concussion, and he has a game in two hours. He is still experiencing symptoms of concussion. However, Athlete H knows that if he tells his coach about the symptoms, his coach will keep him out of the game.*					
9	I feel that Athlete H should tell his coach about the symptoms.	1	2	3	4	5
10	Most athletes would feel that Athlete H should tell his coach about the symptoms.	1	2	3	4	5

Section 5:

Directions: Think about someone who has had a concussion. Check off the following signs and symptoms that you believe someone may be likely to experience AFTER a concussion.

Hives	Feeling in a "fog"
Headache	Weight gain
Difficulty speaking	Feeling slowed down
Arthritis	Reduced breathing rate
Sensitivity to light	Excessive studying
Difficulty remembering	Difficulty concentrating
Panic attacks	Dizziness
Drowsiness	Hair Loss

Scoring Key for RocKAS

Section														
1			*2*			*3*			*4*			*5*		
Item	*Correct Response*	*Index*[a]	*Item*	*Correct Response*	*Index*	*Item*	*"Safer" Response*[b]	*Index*	*Item*	*"Safer" Response*	*Index*	*Symptom*	*Distractor/ Legitimate*[c]	*Index*
1	TRUE	CKI	1	FALSE	CKI	1	SD/D	CAI	1	SA/A	CAI	Hives	D	NI
2	FALSE	NI	2	TRUE	CKI	2	SA/A	CAI	2	SA/A	CAI	Headache	L	CKI
3	TRUE	CKI	3	FALSE	CKI	3	SA/A	NI	3	SD/D	CAI	Difficulty Speaking	D	CKI
4	TRUE	VS				4	SA/A	NI	4	SD/D	CAI	Arthritis	D	NI
5	FALSE	CKI				5	SD/D	CAI	5	SD/D	CAI	Sensitivity to Light	L	CKI
6	FALSE	CKI				6	SD/D	CAI	6	SD/D	CAI	Difficulty Remembering	L	CKI
7	FALSE	CKI				7	SA/A	CAI	7	SA/A	CAI	Panic Attacks	D	NI
8	TRUE	CKI				8	SD/D	NI	8	SA/A	CAI	Drowsiness	L	CKI
9	FALSE	CKI							9	SA/A	CAI	Feeling in a "Fog"	L	CKI
10	TRUE	VS							10	SA/A	CAI	Weight Gain	D	NI
11	FALSE	CKI										Feeling Slowed Down	L	CKI
12	FALSE	CKI										Reduced Breathing Rate	D	NI
13	TRUE	CKI										Excessive Studying	D	NI
14	FALSE	CKI										Difficulty Concentrating	L	CKI
15	FALSE	VS										Dizziness	L	CKI
16	TRUE	CKI										Hair Loss	D	NI
17	TRUE	CKI												
18	FALSE	CKI												

[a]CKI = Concussion Knowledge Index; CAI = Concussion Attitude Index; VS = Validity Scale; NI = no index—item not part of any index. [b]SD/D = strongly disagree/disagree; SA/A = strongly agree/agree. [c]L = legitimate symptom; D = distractor symptom.

Rehabilitation Recommendation After Concussion (RehabRec)

List three things you would recommend to someone who has suffered a concussion to help with their recovery process:

____

____

____

Appendix F – Brochure for survey recruitment

OUR RESEARCH

Our team is interested in your views regarding your injury and what you think about exercising to manage symptoms after the injury.

You can help us by completing **a survey using the link or QR code below**. Your responses will be useful to help us understand how people think about exercising after a concussion. You responses can also help us design suitable exercise programs for individuals suffering from symptoms after a concussion.

Survey link:
https://bit.ly/Exerciseforconcussion
OR
Scan code with mobile device:

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Concussion Research

Queensland Government
Metro North
Hospital and Health Service

QUT

Brochure_V8_300620

ABOUT...

Concussion is estimated to affect more than **18 000** Australians each year[1]. Most people will make a full recovery within days to weeks. However, a small proportion of individuals can suffer from ongoing problems such as:

- **Headaches**
- **Dizziness**
- **Sleep problems**
- **Memory**
- **Concentration**

At times, these symptoms can be present for prolonged periods after a head injury and **disrupt employment, studies and/or relationships.**

[1] *Brain Injury Australia*

FACTS...

- Concussions can occur **without** any direct impact to the head
- You **do not need to lose consciousness** to have a concussion
- Concussions can happen **even if you are wearing a helmet**
- People with similar injuries **can have very different experiences** after a concussion
- Symptoms can start **days or weeks after** a concussion

POST- CONCUSSION SYMPTOMS...

RECOVERY...

Rest is important immediately after the injury, but studies have shown that resuming gradual **physical activity** after 24-48hrs can help to reduce symptoms. However, everyone is different. How active you have been before the injury, how you feel after the head injury and your views about exercise can shape your decision to take part in physical activities after a concussion.

Appendix G - Online survey to assess intentions to exercise for post-concussion recovery

<u>Demographic Questions</u>

In this section, we are interested in finding out some details about you.

What is your age in years? (Please respond using numbers only)

____

What is your gender?
Male
Female
Other
Prefer not to disclose

What is your ethnicity?
Caucasian
Aboriginal or Torres Strait Islander
South Asian
Southeast Asian
North Asian
African
Pacific Islander
Other (Pls specify):
____

In which state or territory do you reside? If outside of Australia, please specify the country in the text box below:
QLD
NSW
VIC
ACT
TAS
SA
WA
NT
Others (Pls specify):
____

How many years of education have you completed? (Please respond using numbers only):

____

What is the highest qualification you have achieved?
No education
Primary school
High school (no certificate)
High school graduate
Trade/technical/vocational training
University (no degree)
Associate degree
Bachelor's degree
Master's degree
Doctorate degree

What is your current employment status?
Unemployed
Home duties
Casual worker
Part-time worker
Self-employed

Permanent employee

What is your primary occupation?
Manager
Professional
Technician and trade worker
Community and Personal service worker
Clerical and Administrative worker
Sales worker
Machinery Operators and drivers
Labourers
Student
Others:
____

What is your usual gross annual income (before tax)?
$0-$18,200
$18,201-$37,000
$37,001-$90,000
$90,001-$180,000
$180,001 and over

What is your current relationship status?
Single-never married
Married
De-facto
Widowed
Divorced
Separated

Sports Participation

Do you play contact sports?
Yes
No

What type of contact sports do you play?
Australian Rules
Basketball
Boxing
Hockey
Ice Hockey
Marital Arts
Rugby League
Rugby Union
Soccer
Volleyball
Wrestling
Others: ___________

Which one of the following categories best describe the level you play at? (If you play multiple sports at various levels, indicate the highest level that you play one or more sports).

Professional or elite level
State level
Regional level
Recreation

Concussion History and Education

Have you experienced a concussion in the past?
Yes
No

If yes, how many concussions have you experienced in the past?

____

Have you experienced a concussion in the last 6 months?
Yes
No

If yes, when did you have the most recent concussion?
Less than 1 to 2 weeks ago
More than 2 weeks to 4 weeks ago
More than 1 month to 2 months ago
More than 2 months to 4 months ago
More than 4 months to 6 months ago

Have you studied or been taught about concussion?
Yes
No

If yes, how was the concussion education delivered? If you have received education via multiple sources, then please select all appropriate options.

Brochures
Via a coach or trainer
Online (i.e., Youtube)
Formal classroom training
Medical professional
Social media
Smartphone apps
TV ads
Interactive website
Radio ads
Newspaper ads or articles
Other

<u>Treatment and Validation of Injury</u>

Did you seek medical treatment for your concussion?
Yes
No

If yes, were you treated at hospital within 24 hours for your most recent concussion?
Yes
No
Maybe

Did you lose consciousness when you had the concussion?
Yes
No
Maybe

Do you have a clear memory of the events immediately before and after the most recent concussion?
Yes
No
Maybe

Are you still receiving any form of treatment for your most recent concussion?
Yes
No

Can you recall what caused your concussion(s)?
Sports and recreation
Motor vehicle accident
Workplace accident
Assault
Fall
Cannot recall
Ohers: (Pls specify):
____

Can you recall if you were advised by at least one healthcare professional to rest for more than 2 days after your most recent concussion?
Yes
No
Maybe

Do you feel that you have recovered a 100% since your most recent concussion? (On a scale of 0-100)
0 ---100
Not recovered at all *Complete recovery*

If you think you have persistent symptoms from the concussion that should have cleared up by now, how would you seek treatment? (Please select the most likely option)
See a doctor
Go to a hospital emergency department
Go to a concussion clinic
Consult a psychologist
Search the internet for help
Do nothing
Others (Pls specify:)

____

Have you resumed normal activities (i.e., return to work/sports/school) since your most recent concussion?
Yes
No

For your most recent concussion, did you or are you in the midst of seeking compensation (e.g., insurance claims, work compensation)?
Yes
No

For your most recent concussion, were you or are you currently involved in any litigation/investigation (e.g., court hearing, police investigation)?
Yes
No

Do you have a current psychiatric diagnosis (e.g., anxiety disorder, depression, bipolar, schizophrenia)?

Yes
No
Do you have any neurological disorders/conditions (e.g., brain injury, stroke, Parkinson's disease, Alzheimer's disease)?

Yes
No

Exercise Behaviour
In this section, we are interested to find out about your current views on exercise and your fitness habits.

Exercise is important to me.
Yes
No

I have exercised regularly in the past 12 months.
Yes
No

If yes, how often did you exercise in the past 12 months?
Everyday
1-2 times a week
3-4 times a week
5-6 times a week
More than 6 times a week

How long did you exercise per session?
30 min or less
31-60 min
More than 1-2 hours
More than 2 hours

What form of exercise have you participated in during the past 12 months? (You can select more than one response)
Walking
Running
Self-training in gym
Gym-based classes
Hiking
Swimming
Yoga

Team sports
Others (pls specify)

____

ACTIVE HEADS PROGRAM (Theory of Planned Behaviour Questions)

For those **NOT reporting a history of concussion**, the following excerpt was presented:

Please read the following information before responding to the questions in the next few sections.
A concussion is a head injury that is caused by a direct or indirect impact resulting in the head and brain to move rapidly. This movement can cause chemical changes in the brain and possibly damage brain cells. While most people who have a concussion recover, a minority report persistent symptoms such as headaches and concentration problems that can last for months or years. Increasingly, studies have shown that exercising after a short period of rest might improve symptoms after a concussion.
*For the questions that follow, **assume that you had a concussion 7 days ago**. You have been made aware of an exercise program called Active-Heads. This program is designed to help people recover from persistent symptoms after a concussion.*
The Active-Heads program requires you to take part in a gym-based exercise program that combines aerobic and resistance training. This program will be personalised based on your fitness level. You will be taught how to do the exercises, and supervised while you do them, so that you can get help and make adjustments if needed. The intensity of the program will be increased progressively, at a pace that is comfortable for you. You are required to participate in the Active-Heads program for 3-8 weeks depending on how quickly you recover from your symptoms.
We want to know what you think about Active-Heads, and if you would participate in it. Take a moment to consider what the program requires, and how it sounds to you. In a moment, we will ask you to tell us your views.

For those reporting a **history of concussion in the past 6 months**, the following excerpt was presented:

Please read the following information before responding to the questions in the next few sections.
A concussion is a head injury that is caused by a direct or indirect impact resulting in the head and brain to move rapidly. This movement can cause chemical changes in the brain and possibly damage brain cells. While most people who have a concussion recover, a minority report persistent symptoms such as headaches and concentration problems that can last for months or years. Increasingly, studies have shown that exercising after a short period of rest might improve symptoms after a concussion.
*For the questions that follow, **recall your most recent concussion**. You have been made aware of an exercise program called Active-Heads. This program is designed to help people recover from persistent symptoms after a concussion.*
The Active-Heads program requires you to take part in a gym-based exercise program that combines aerobic and resistance training. This program will be personalised based on your fitness level. You will be taught how to do the exercises, and supervised while you do them, so that you can get help and make adjustments if needed. The intensity of the program will be increased progressively, at a pace that is comfortable for you. You are required to participate

in the Active-Heads program for 3-8 weeks depending on how quickly you recover from your symptoms.

We want to know what you think about Active-Heads, and if you would participate in it. Take a moment to consider what the program requires, and how it sounds to you. In a moment, we will ask you to tell us your views.

Now what do you think about the Active-Heads program?

5-pt Likert scale responses (1-strongly disagree, 2-disagree, 3-neither agree nor disagree, 4 – agree, 5- strongly agree)

If I took part in Active-Heads, I would feel better.

If I took part in Active-Heads, my symptoms would improve.

If I took part in Active-Heads, it would be safe.

If I took part in Active-Heads, it would be worth the time.

If I took part in Active-Heads, it would be positive.

If I took part in Active-Heads, it would be sensible.

If I took part in Active-Heads, I would feel healthier.

If I took part in Active-Heads, I would feel happy.

5-pt Likert scale responses (1-strongly unlikely, 2-unlikely, 3-neutral, 4 – likely, 5- strongly likely)

If took part in Active-Heads, it would take too much of my time.

If took part in Active-Heads, I would feel that I was doing something towards my recovery.

If took part in Active-Heads, it would exacerbate my concussion symptoms.

If took part in Active-Heads, it would incur significant out-of-pocket costs for me.

If took part in Active-Heads, it would give me an opportunity to meet others with similar symptoms.

5-pt slider scale responses (1-undesirable, 5-desirable)

Spending a lot of time on an exercise program that helps with my concussion recovery is:

Doing something positive on my part to help with my concussion recovery is:

Taking part in an exercise program despite a risk of symptoms getting worse is:

Spending money out-of-pocket for an exercise program that could potentially help with my recovery is:

Meeting other people with a similar condition like me in the exercise program is:

5-pt Likert scale responses (1-strongly disagree, 2-disagree, 3-neither agree nor disagree, 4 – agree, 5- strongly agree)

Most people who are important to me would be interested in participating in Active-Heads.

People like me would be interested in participating in Active-Heads.

Most people who are important to me would approve of me participating in Active-Heads.

People like me would want me to participate in Active-Heads.

5-pt slider scale responses

Athletes would think I __________ participate in Active-Heads to help with my recovery.
(1 – should not, 5 – should)

Doctors would ___________ of my participation in Active-Heads.
(1-disapprove, 5 – approve)

My family members ____________ want me to participate in Active-Heads to help with my recovery.
(1-would not, 5-would)

What athletes think of the Active-Heads program is important to me.
(1-not at all, 5-very much)

What doctors think I should do matters to me.
(1 -not at all, 5-very much)

Doing what my family members want me to is important to me.
(1-not at all, 5-very much)

5-pt Likert scale responses (1-strongly disagree, 2-disagree, 3-neither agree nor disagree, 4 – agree, 5- strongly agree)

I am confident that I can participate in the Active-Heads program.
I am confident of doing the activities in the Active-Heads program.

I am confident that I can complete the Active-Heads program.

The decision to participate in Active-Heads is beyond my control.

Whether I participate in Active-Heads or not is entirely up to me.

<u>5-pt slider scale responses</u>

I may not have the time to take part in an exercise program like Active Heads for recovery after a concussion.
(1-unlikely, 5-likely)

I may not be feeling energetic to participate in an exercise program like Active-Heads after a concussion.
(1-unlikely, 5-likely)

I may not be feeling unwell enough to participate in an exercise program like Active-Heads after a concussion.
(1-unlikely, 5-likely)

I am __________ to make time to participate in an exercise program like Active-Heads for recovery after a concussion.
(1-less likely, 5-more likely)

I am _________ to participate in a program like Active-Heads after a concussion if I am not feeling energetic.
(1-less likely, 5-more likely)

I am __________to participate in a program like Active-Heads after a concussion if I am not unwell enough.
(1-less likely, 5-more likely)

<u>5-pt Likert scale responses (1-extremely unlikely, 2-unlikely, 3-neither likely nor unlikely, 4 – likely, 5- extremely likely)</u>

I intend to do Active-Heads.

I expect to do Active-Heads.

I want to do Active-Heads.

The likelihood of me participating in Active-Heads is:

I plan to do Active-Heads.

<u>Feasibility of exercise program</u>

<u>5-pt Likert scale responses (1-strongly disagree, 2-disagree, 3-neither agree nor disagree, 4 – agree, 5- strongly agree)</u>

I would be interested in attending a trial session of the Active-Heads program before I decide on committing to it.

Watching a demo video of Active-Heads would help me decide if I can commit to it.

There would be a better chance of me to participate in Active Heads if it was home-based.

The Active-Heads program sounds too intensive for me.

The Active-Heads program sounds too time-consuming for me.

I would participate in the Active-Heads program if there was no costs (e.g., Medicare paid).

The duration of the ACTIVE-HEADS program does not matter to me as long as it makes me better.

For me, an ideal duration for the ACTIVE-HEAD program is:

3-4 weeks
More than 4 to 6 weeks
More than 6 to 8 weeks
More than 8 weeks

Multiple response checkbox

What are some possible reasons that could make it difficult to participate in the Active-Heads program?

Distance from gym

Lack of time

Work commitments

Lack of interest

Too lazy to exercise

Already training or following a program

Lack of transportation

Health concerns

Prefer other treatments

Prefer other forms of non-gym-based exercise (e.g., stationary bike)

Others (pls specify)
____

For selected responses:

You have selected distance from the gym as a possible reason to make it difficult to participate in Active-Heads. What is the maximum distance you would travel to participate in a program like this?

Less than 5km
5-10 km
11-20 km

More than 20km

You have selected lack of time as a possible reason to make it difficult to participate in Active-Heads. How much time you would be willing to spend each week on a program like Active Heads?

Less than 1 hour
1-2 hours
More than 2 hours to 4 hours
More than 4 hours

5-pt Likert scale responses (1-strongly disagree, 2-disagree, 3-neither agree nor disagree, 4 – agree, 5- strongly agree)

The idea of having a professional guiding me in Active-Heads makes me want to do the program.

The idea of Active-Heads being personalised to my fitness levels makes me want to do the program.

The idea of having a combination of aerobic and strength training in Active-Heads makes me want to do the program.

The idea of meeting other people with a similar injury like me in Active-Heads makes me want to do the program.

The idea of getting health and fitness information from Active-Heads makes me want to do the program.

Open-ended responses

Please indicate if there are other features of an exercise program that you would find attractive:
____

Rank-order response

If given a choice of options to treat your persistent symptoms after your recent concussion, what is your order of preference for treatment (1-most liked, 6-least liked)?

Counselling

Psychological therapy (e.g., cognitive behavioural therapy)

Exercise

Education on post-injury management

Meditation (including mindfulness-based programs)

Others