Understanding the impact of sport-related concussion and physical pain on mental health, cognitive ability, and quality of life

EDGE HILL UNIVERSITY

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I. Declaration

I declare that this thesis is my own work carried out under the normal terms of supervision. I confirm that this work has not been submitted for any comparable academic award.

II. Acknowledgements

I would like to thank Edge Hill University for providing the funding for this thesis and making this research possible. A more personal thanks goes to my supervisory team Dr. Alex Bahrami Balani, Dr. Adam Qureshi, and Dr. David Marchant for their guidance and support throughout this project and beyond. The effort and dedication from all that participated in this project cannot go unnoticed. Without you this thesis would not exist, and I encourage you to continue to take part in research whenever possible.

I would like to thank all my family and friends for their support over the past three years especially my mother Julie and father Allan, as well as brothers Thomas and Lewis. To my partner Katie, for always supporting and believing in me. Beyond this, Katie would consistently keep my feet on the ground, perhaps without knowing, and was a constant reminder of what is important in life and the impact we can have outside of research.

This reminder was emphasised in July 2022 with the passing of my grandmother. A huge loss for myself and my family. This thesis is dedicated to her.

III. Abstract

An issue within concussion research is that it often overlooks the role of physical pain. Poor mental health, impaired cognitive ability, and reduced quality of life are all associated with concussion. However, these three broad outcomes are also linked with experiencing physical pain, and therefore this project aimed to better understand whether concussion or physical pain is responsible for these negative outcomes. Studies 1 and 2 suggest that physical pain is greatly linked with poorer mental health and reduced quality of life, while study 3 corroborates these findings and adds that concussion history is more responsible for cognitive impairment. Study 4 highlighted some of the issues with remote cognitive testing across different time-points but further emphasised the importance of assessing physical pain in athletes with and without history of concussion. Study 5 emphasised the dangers of taking part in contact sports, with women, those in physical pain, those that have previously sustained sport-related concussion (SRC) and those that engage in contact sports significantly more likely to develop depression. Based on the findings from studies 1-5, we wanted to understand why those that take part in contact sports where SRC is common, do so and therefore study 6 interviewed amateur rugby players to investigate their attitudes and knowledge base of concussion. Poor duty of care may be prevalent in amateur rugby, which can result in poor attitudes and knowledge increasing the chance of continuing participation following a suspected concussion. An increased emphasis on improving duty of care could relieve these poor attitudes and the behaviour following suspected concussion. Finally, although physical pain is key in findings of studies 1-5, the way in which we measured this may be limited and we therefore propose a new Localised Pain Scale that could be more robust. Overall, this thesis refines what we currently know about the effects of concussion and physical pain by highlighting the outcomes associated with both.

Table of Contents

Introduction

This project began in October 2019 and was successfully defended in January 2023. In this time, the landscape of concussion research and the general conversation surrounding this topic changed. This area has been heavily scrutinised in the media, with legal action taken from a group of ex-professional rugby players in December 2020. The claimants include World Cup-winning Steve Thompson who now suffers from early-onset dementia and probable CTE. Thompson was diagnosed in December 2020, aged 42, and claims to having no memory of the world cup victory he was part of. He published a book titled "Unforgettable: Rugby, Dementia and the Fight of My Life" in February 2022 which was followed up by a BBC documentary titled "Head On: Rugby, Dementia and Me" in October of the same year. Both his book and documentary have been well received. Over 20 players are involved in the litigation, representing more than 225 players suffering from neurological impairments.

Football has also turned its attention to the negativity surrounding concussion and the negative consequences of head injury. Again, in December 2020, English Premier League clubs agreed in principle to take part in the International Football Association Board (IFAB) trial of additional permanent concussion substitutions (APCSs) which began in February 2021. Although this does demonstrate some consideration for protecting footballers from head injury, many have criticised this approach in practice. There is the notion that football should have followed a similar example set by rugby union/league that adopted a temporary replacement for head injury assessment (HIA) in 2015 (World Rugby, 2023).

This distinction between temporary and permanent is what separates its effectiveness in practice. For example, rugby players are protected using the temporary replacement as it ensures that any player with suspected concussion can be immediately replaced with a teammate while they are assessed. This confirms the protection of the player while also serving no numerical advantage to the opposing team. By contrast, footballers are still not protected with the current permanent concussion substitutions because of their nature. It is nonsensical, and perhaps more an exercise of being seen to be doing as opposed to the genuine interest and care of the player. It is impossible for anyone to be completely sure of concussion in a matter of moments, and therefore the permanent concussion substitutions do not give any protection to the player, as if they are used, they cannot be brought back on. This means that managers/coaches have a decision as to either remove the player for an HIA, and then it does not matter on the result as they cannot be brought back on if they are deemed fit or not, or they gamble and keep their player on with suspected concussion. There are even suggestions that FIFA and IFAB are more concerned with how new laws of the game may be manipulated rather than the safety of players (Veuthey, 2020). Since the trial commenced in February 2021, these issues have been ever-present and in January 2023 the Premier League, the Football Association and FIFPRO all supported a call for temporary concussion substitutions, of which the IFAB denied. This call was rejected once again at the IFAB Annual General Meeting in March 2023.

The above demonstrates the growing interest in this area and the increase of media scrutiny surrounding the topic. However, it is not the only debate within this area. Arguably the most difficult aspect of researching or discussing this topic is defining and conceptualising concussion. For example, the terms concussion (sometimes sport-related concussion) mild-traumatic brain injury (mTBI) and traumatic brain injury (TBI) are all used interchangeably when referring to similar events, which makes it difficult to present a case when referring to the negative consequences of these events if we do not know what they are. Concussion and mTBI are commonly accepted as terms representing a mild, non-penetrating, traumatic injury associated with a brief alteration in brain function (Voss et al., 2015). However, using these terms can be problematic as it is also agreed that TBI represents a change in brain function from a traumatic force (Menon et al., 2010). When concussion/mTBI becomes TBI is widely debated and is yet to be agreed upon. Moreover, the interchange between using concussion and mTBI can be debated to with some questioning the use of both. The term *concussion* is the most widely used in the general public, with it cited within the media's portrayal of these events as well as protocols introduced in football and rugby. However, it can be criticised for dilating the seriousness of the event by not referring to it as traumatic or a brain injury as mTBI does. That said, mTBI can also be criticised for the use of *mild* again behaving in the same way as *concussion* perhaps reducing the magnitude of what has happened to the individual. Therefore, it is a difficult area to navigate conceptually, however as the term *concussion* is one that is most widely used within the public domain and within sports teams, and these were our target population, this project utilised this term over the other accepted term *mTBI*.

These conceptual issues bleed into problems with diagnoses. Simply put, a concussion is an energy crisis in the brain, and it is this crisis that presents itself in many ways. The Post-Concussion Symptom Scale identifies 22 different symptoms associated with concussion, some acute and some medium-term. Common symptoms are blurred vision, nausea, headache etc. while some will lose consciousness. Some will not display any symptoms and this is because the severity of the energy crisis will be different for everyone based not only on the force of trauma exhibited to the head/body but other factors such as weight, fitness, diet, and other factors that could influence energy usage. Due to these symptoms typically being mild or absent, unhealthy attitudes towards concussion and managing head injury have developed whereby many athletes will continue competing with a suspected concussion. This is dangerous for themselves and others. One of the consequences of these actions is that there is a disparity in the literature where some utilise samples of clinically diagnosed concussions (Bleiberg et al., 2004; Yang et al., 2015) and some have used self-identified/reported concussions as evidence (Didehbani et al., 2013; Kerr et al., 2012). This must be considered when drawing conclusions regarding the negative consequences of concussion.

Another consideration that must be made when making conclusions regarding the negative consequences of concussion is the number of concussions that that individual has had. This comes with emerging evidence that three or more concussions is linked with cognitive impairment in later life (Lennon et al., 2023). This is not to be misconstrued that there are no negative consequences to sustaining one or two concussions, but to highlight the dangers that repeated concussions have. This provides support for the evolving debate regarding head impacts and neurodegenerative diseases such as Steve Thompson and many other rugby players and nearly half of the England football World cup winning team having been diagnosed or died from different neurodegenerative diseases.

Given that one the most prevalent outcomes associated with concussion is poorer mental health (Gouttebarge & Kerkhoffs, 2021; Wolanin et al., 2015), it is important to consider the other factors that could influence this in sport. This increases the difficulty of researching this area, as there are several factors that could contribute to poor mental health in sportspeople. For example, elite sportspeople are under significant mental and physical demands associated with competing (Balk et al., 2020). This demographic are so finely assessed with large quantities of data obtained to predict level of performance that can inform team selection (Fiander et al., 2021; Roca et al., 2022). Therefore, the level of discipline in every aspect of their lives particularly regarding exercise and diet, to maintain a body composition to compliment optimal performance, could potentially impact mental health.

Injury can be a consequence when striving to maintain these fine margins while coinciding with high performance to retain team selection. Overuse injuries are prevalent, perhaps due to this pressure to maintain these high standards that will ensure being selected to compete. This is in addition to any injury that can occur during competition, commonplace in contact sports across all levels of competition. The mental health of injured athletes can deteriorate as they fear losing their position to a teammate (Smith & Milliner, 1994), a reduction in social support from teammates and coaches (Clement & Shannon, 2011) and a loss of athletic identity (Green & Weinberg, 2001; Tasiemski et al., 2004). Therefore, it is key to understand following concussion whether poor mental health is from the concussion itself or from the social factors associated with injury status. It may be that similar fears fuel negative attitudes towards concussion and lead to non-adherence to concussion protocols. There is evidence that athletes will downplay injuries so to continue competing (Ferdinand Pennock et al., 2020; Meier et al., 2015) and not to appear weak (Liston et al., 2018), and the same applies for athletes with suspected concussion.

This continuation of competing by downplaying injury, may also exacerbate symptoms of physical pain with evidence that athletes will also downplay feelings of physical pain (Cassell, 2004; Messner, 1989). Additionally, it is more than likely that athletes that sustain concussion, will also experience high levels of physical pain due to the nature of the event. Both concussion and physical pain are associated with poor mental health (Gouttebarge & Kerkhoffs, 2021; Ledoux et al., 2022; Walker & Marchant, 2020; Walker & McKay, 2022), impaired cognition (Bleiberg et al., 2004; Hageman et al., 2014; Moriarty et al., 2016), and reduced quality of life (Niv & Kreitler, 2001; Voormolen et al., 2019; Weber et al., 2019), and therefore this raises suspicion as to whether it is concussion or physical pain that led to these negative outcomes, and uncovering this is one of the main aims of this project.

In short, it appears that concussion in sport is like other physical injuries that are considered *knocks* such as mild pain to different joints to the knee or ankle that can be *run off*. Promoting attitude change is difficult when some do not present any symptoms, and those that do may display mild cases. Instead, concussion should be of high priority to sportspeople and their teams as it is a serious brain injury with severe and sometimes fatal consequences.

1. Chapter 1: Literature Review

1.1 Introduction

Despite numerous potential social and psychological benefits associated with sports participation (Andersen et al., 2019), sport-induced brain injuries such as sport-related concussion (SRC) pose a threat to many athletes (Manley et al., 2017). SRC is more common in contact sports (Bakhos et al., 2010), with an estimated 1.6-3.8 million cases annually in the USA (Collins et al., 2018). This figure is much higher than the 300,000 reported SRC's twenty years prior (Sosin et al., 1996), suggesting athletes are at high risk of sustaining SRC and they are being identified more often. Though it must be noted that some of the rise in cases may be due to improved reporting of SRC. Interestingly, SRC has also been recorded in non-contact sports such as cycling (Heron et al., 2020; Rice et al., 2020) and gymnastics (Eng & Makovitch, 2020), further highlighting the increased prevalence of sustaining SRC. The risks involved in contact sports have been widely accepted by competitors and spectators (DeKosky et al., 2018), despite evidence that tackling technique is a major risk factor for the tackler in ball sports (Suzuki et al., 2020). Additionally, difficulties in pitch-side identification of SRC could contribute to sport culture that favours continuing participation following suspected SRC (McCrea et al., 2020). This attitude is further highlighted when assessing sportspersons' attitudes to head injury, with evidence that athletes may well be knowledgeable of head injury risks associated with their sports, but often possess unsafe attitudes towards continuing participation despite suspected SRC, that may negatively impact their long-term health and further injury risk (Hutchinson et al., 2019). Similar negative attitudes have also been found in the coaches (Kerr et al., 2020). It is, therefore, important that athletes are made explicitly aware that repeated exposure to SRC has the potential to cause major long-term health complications including mood disorders such as depression (Covassin et al., 2012; Solomon et al., 2016) and anxiety (Yang et al., 2015).

The fact that there seems to be overlapping occurrences of concussion and depression symptoms such as sleep disturbances and irritability, as well as concentration and memory disturbances have inspired research into this area. Further to evidence of SRC impacting mood (Covassin et al., 2012; Solomon et al., 2016; Yang et al., 2015), research has found different types of mild cognitive impairments in post-concussed people. These can include impairment in short-term memory - STM (Hylin et al., 2013; Mayers, 2013), long-term memory - LTM (Mayers, 2013; Ozen et al., 2013), working memory - WM (Gosselin et al., 2012; Li et al., 2016; Sicard et al., 2018), prospective memory - PM (Lajeunesse et al., 2019), inhibitory control - IC (Ho et al., 2018; McGowan et al., 2019; Moore et al., 2014), and cognitive flexibility - CF (Hume et al., 2017; McGowan et al., 2018). As many athletes may also exhibit declines in mental health and cognition following SRC, research investigating the quality of life in this demographic has increased, with evidence showing that longer recovery time results in reduced quality of life reporting (McLeod et al., 2019). Treatment history is also noteworthy with evidence showing that whether an athlete receives treatment or not, and when that treatment started, are key to long term outcomes of SRC, with delays and poor treatment common in sport (Kontos et al., 2020).

Additionally, there is evidence of higher prevalence rates of non-sport-related concussion (NSRC) compared to sport-related concussion (Breck et al., 2019). NSRC may occur during activities in everyday living e.g., traffic or work-related accidents, falls, recreation, acts of violence, or explosions (Sojka, 2011). In view of previous research suggesting elevated rate in depressive symptoms (Gouttebarge & Kerkhoffs, 2021), impaired cognition (Hume et al., 2017; Hylin et al., 2013; McGowan et al., 2019; Moore et al., 2014; Ozen et al., 2013), and reduced quality of life (Gard et al., 2020) associated with SRC, it is plausible these aftereffects may also be present in NSRC cases. Therefore, when assessing concussion, it is advantageous to investigate NSRC and SRC simultaneously (Sojka, 2011) to isolate the concussive event, especially considering the intense physical demands and psychological stress associated with competitive sporting participation (Ströhle, 2019). Sojka (2011) states that when studying SRC, many researchers are interested in the time for "return to competition" as a measure of recovery and therefore parallels should be made to NSRC with "time for return to work" suggested as an alternative measure. Therefore, measuring recovery period should be recorded for both SRC and NSRC; through return to competition for the former and return to work for the latter. This project, therefore, intends to assess both SRC and NRSC sufferers.

1.2 Mental Health

1.2.1 Depression

The prevalence of depression in young adults (18-25 years old) is higher than in older age groups. Wolanin et al. (2016) found young adults by this definition displayed an 8.7% prevalence rate during a 12-month span which is visibly higher than the 3.8% prevalence found in the general population (WHO, 2023). Other studies have recorded prevalence rates as high as 21% (Yang et al., 2007) and 51% (Walker & Marchant, 2020) in young adult student athletes. While much of the literature suggests that sport participation acts as a protective factor against depression (Babiss & Gangwisch, 2009), emerging evidence points towards the opposite, suggesting that competing in sport may be a risk factor for depressive mood (Wolanin et al., 2016). The association between sport participation and depression could be explained through the higher risk of sustaining SRC's (McAllister & Wall, 2018) and the negative impact this may have on mood (Turner et al., 2017; Yrondi et al., 2017). Additionally, it is also possible that exposure to prolonged stress can lead to depression and other mood disorders (Seo et al., 2017), as well as hindering training and athletic performance (Gardner & Moore, 2006), placing athletes as a vulnerable demographic regarding the risk of poor mental health. Research into SRC's has perhaps received attention due to the rise in media coverage of the effects of concussion, with increased suicidality reports of former elite professional athletes who have had sustained multiple SRC's (Vargas et al., 2015) with similar reports found in youth sport (Clacy et al., 2019). Well-documented case studies like Aaron Hernandez, the former NFL player, who committed multiple murders, have also raised the profile of head injury in sport. His posthumous diagnosis of chronic traumatic encephalopathy (CTE) raised questions about how this may have affected his behaviour, even though there is little evidence to suggest that CTE exacerbates psychopathy leading to homicidal behaviour (Golden & Zusman, 2019). In addition, Hernandez committed suicide in his prison cell, an act that is heavily linked with SRC by the media, once again, despite little scientific evidence to support these claims (Datoc et al., 2020). Nevertheless, the profile of head injury in sport, particularly SRC, is rising. Due to the popularity of contact sports where SRC is prevalent (Bakhos et al., 2010), this links athletes with heightened risks of sustaining SRC's and subsequently displaying depressed mood.

Although research has highlighted that SRC can negatively affect mood in various levels of competitive sport ranging from amateur to professional (Melo & Filgueiras, 2018; Rice et al., 2018), many studies opt to utilise student athlete samples when examining the impact of SRC on depression (Vargas et al., 2015). This technique is perhaps due to the accessibility of this demographic to researchers as well as the high proportion of participants that study at university who also compete in sport. British Universities & Colleges Sport (BUCS) is the governing body for university sport in the UK and comprises of over 6000 sports teams from 170 institutions competing in 50 different sports. Therefore, although there is evidence that sporting participation generally decreases when attending university (Gucciardi & Jackson, 2015), there are still many students in the UK that engage in competitive sport alongside their studies, hence increasing their risk of sustaining SRC. As well as this, there are also indications of the vulnerability of student athletes exhibiting poor mental health (Kroshus et al., 2018; Wolanin et al., 2015), providing a fair rationale for assessing this demographic post-concussion.

As opposed to many studies that have aimed to record prevalence rates of depression in student athletes (Proctor & Boan-Lenzo, 2010; Wolanin et al., 2016), Vargas et al., (2015) were interested in assessing whether there was a difference in prevalence rates between student athletes that had experienced concussion compared with student athletes with no concussion history. One hundred and twenty-six participants were included in the study with post-concussed participants making up to two-thirds of the sample. The Beck Depression Inventory (BDI-II; Beck et al., 1961) recorded quantitative scores of depressive symptoms at two different time points; before and after a concussive event for the post-concussed group, and a matched design was used to also measure healthy controls at two separate time points. Analyses revealed that 20% of the concussed athletes displayed a reliable increase in depressive symptoms following a concussive event, significantly greater than the 5% of participants in the healthy control group.

Vargas et al's. (2015) findings depict elevated depressive symptoms in people with concussion. It is commonly accepted that the BDI-II that the authors used is considered among the leading depressive symptomology questionnaires (Shafer, 2006) alongside the Center for Epidemiological Studies Depression Scale (CESD; Radloff, 1977), the Hamilton Rating Scale for Depression (HRSD; Hamilton, 1960) and the Zung Self-Rating Depression Scale (SDS; Zung, 1965). However, which of these tools that is used is often determined by the research questions. For example, Pryor et al. (2016) utilised the CESD when attempting to determine if concussive events increase the incidence of depression in semi-professional and professional North American football players. This is because the authors used the recommended cut-off score of ≥16, to determine whether participants were experiencing some form of depression (Husaini et al., 1980). Pryor et al. (2016) found that athletes that scored over this cut-off threshold sustained a significantly greater number of lifetime concussions. Further analysis also revealed significantly higher CESD scores in players who had sustained three or more concussions compared to those that have sustained two or less. These findings indicate concussion seems to have a negative impact on depressive mood which is corroborated with the group of athletes that had sustained three or more concussions recording significantly higher depressive symptoms than those that had sustained two or less concussions (Pryor et al., 2016). While BDI-II also has cut-off scores, these are separated into four different categories (minimal, mild, moderate, and severe depressive symptoms; Seppänen et al., 2022). As the current project intends to use binary logistic regression, the CESD that has a binary cut-off point is deemed more appropriate.

Research on the role of NSRC on depression is much sparser. One of the few works of research was conducted by Chrisman and Richardson (2014) who provided evidence of NSRC history being associated with higher prevalence of diagnosed depression, indicating that NSRC exposes teenagers to a 3.3-fold greater risk of depression. While this research again presents an alarming link between NSRC and depression, no symptomology questionnaire was administered in this study. Instead, history of depression diagnosis was attained from parent reports which did not capture the participant's mood at the time of participation. Therefore, there was less control over when the concussion occurred in relation to depression diagnosis which is important in this area of research. This lack of research and control suggests studies should aim to utilise symptomology questionnaires, like the CESD, to ensure concussion occurred prior to depressed mood.

As with many areas of research, there are confounding factors that make it difficult to isolate the role of single variables and establish causality links. Concussion is not exempt from this rule, with post-concussion physical pain being one of the most prevalent consequences of a concussive event (Mollayeva et al., 2017; Nampiaparampil, 2008), and pain having negative effects on depressed mood (Humo et al., 2019; Nekovarova et al., 2014; Walker & Marchant, 2020). Using the recommended cut-off score of the CESD (≥16; Husaini et al., 1980), Walker and Marchant (2020) found that participants reporting depressive symptoms scored significantly higher physical pain than those without depressive symptoms. The work of Nekovarova et al. (2014) can help explain the findings reported by Walker and Marchant (2020). There is evidence that depression can precede pain and vice versa, which suggests the existences of a shared neural mechanism (Blackburn-Munro & Blackburn-Munro, 2001; Chou, 2007) and this was further highlighted by Nekovarova et al. (2014) reporting an overlap between pain pathways and pathways of Major Depressive Disorder (MDD), including serotonergic, noradrenergic, and glutamatergic which are critical for mood regulation. Therefore, physical pain, whether exacerbated by concussion or just in isolation, could be linked to elevated depressive symptoms. With findings suggesting that physical pain often accompanies concussion long after the event (Voormolen et al., 2019), this implies these factors require simultaneous investigation.

1.2.2 Anxiety

Depression is among the most researched emotional changes post-concussion, (Broshek et al., 2015; Snell et al., 2016; Willer & Leddy, 2006), however, with anxiety often thought to be linked with depressive mood, there have been increased efforts to include anxiety alongside depression in research and highlighting their comorbidity (Walker & Marchant, 2020; Yang et al., 2015). The prevalence of anxiety disorders in the UK was 18% in 2013 (Fineberg et al., 2013) and rose 51% between 2004 and 2017 (Vizard et al., 2018). Following the COVID-19 pandemic that began in early Spring 2020, it is evidenced that the rate has increased (Pierce et al., 2020). It is suggested that both stress (Jardin et al., 2018;

Konstantopoulou et al., 2020) and concussion (Auclair-Pilote et al., 2019; Carlson et al., 2020; Yang et al., 2015) are risk factors for both depression and anxiety, and therefore simultaneous investigation of depression and anxiety is justified.

Yang et al. (2015) compared psychological symptoms at baseline and post-concussion in 67 student athletes that participated in various contact sports. The CESD questionnaire recorded the level of depressive symptoms among the athletes whereas the State-Trait Anxiety Inventory (STAI; Speilberger et al., 1970) recorded trait anxiety. These were taken at baseline (during pre-season) and one week after sustaining concussion. The STAI consists of two 20-item forms measuring both state and trait anxiety and is a well validated measure of state-trait anxiety that is often used alongside assessments of depressive symptoms (Levit et al., 2018; Sheehan et al., 2018; Walker & Marchant, 2020). Analyses revealed that 19.8% of the athletes reported experiencing depressive symptoms and 33.8% reported experiencing anxiety (Yang et al., 2015). This was coupled with 14.1% that reported experiencing both disorders post-concussion. However, it was found that concussed athletes that displayed any level of baseline trait anxiety symptoms did not display an increase in post-concussion depression and state anxiety symptoms, suggesting that trait anxiety is not affected by SRC. However, this could be due to the authors dichotomising participants, grouping them to those that scored 0 on the STAI and those that scored over 0. It is likely that most people will display some level of trait anxiety without this being linked to anxiousness that could negatively impact life, which could explain why SRC was found to have no influence here. The study evidenced that post-concussion symptoms of depression significantly co-occurred with symptoms of state anxiety which corroborates past research by Yang et al. (2007) showing that student athletes experiencing depressive symptoms display higher scores of state-anxiety and trait-anxiety. There is also evidence of both depression and anxiety exhibited following SRC, so demonstrating their comorbidity indicating that the two disorders warrant simultaneous investigation.

Carlson et al. (2020) provide further evidence for the influence of concussion on anxiety symptoms, with significant correlations found between somatic-related anxiety symptoms and concussion symptoms. But this relationship seems to be driven by psychological rather than physical concussion symptoms which contradicts the role that pain has on mood (Mollayeva et al., 2017; Nampiaparampil, 2008; Walker & Marchant, 2020). This could be due to the low sample size in Carlson et al.'s (2020) study with only 42 student athletes assessed (21 control vs. 21 post-concussed), however, the control group displayed no significant relationship between concussion and anxiety symptoms, suggesting that concussion may have contributed to elevated anxiety symptoms in the post-concussed group.

In addition to physical pain often being present following concussion, altered routine due to injury and subsequent concussion protocols could negatively impact mental health. Although there is evidence of elevated anxiety symptoms in those that have sustained concussion (Carlson et al., 2020; Yang et al., 2015) injured athletes also display lower state-anxiety than non-injured controls (Walker & Marchant, 2020), perhaps due to reduced sporting pressures during injury. However, this could be explained by levels of physical activity participants engaged in following the concussive event, with evidence that this may help alleviate anxiety symptoms in this demographic (Womble et al., 2020). Therefore, knowledge of injury history and recovery time are required when assessing post-concussed athletes, to improve the knowledge base of appropriate recovery time and physical activity within this period.

1.2.3 Affect

Affect refers to the underlying experience of feeling, emotion, or mood (Hogg et al., 2010). Given this definition, there is a clear overlap between affect and mental health disorders such as depression and anxiety which influence feelings, emotions, and overall mood, which has led to affect being incorporated into mental health research (Christodoulou et al., 2009; Rooks et al., 2017). The Positive and Negative Affect Scale (PANAS; Watson et al., 1988) is a well-validated measure of affect that has been utilised alongside the CESD and STAI (Christodoulou et al., 2009; Rooks et al., 2017), however, to the researcher's knowledge this has not yet been attempted with post-concussed individuals. Therefore, with links between concussion and poorer mental health (Turner et al., 2017; Yrondi et al., 2017) and affect and mental health (Christodoulou et al., 2009; Rooks et al., 2017), it is possible that concussion and affect are associated, which warrants exploration.

1.3 Cognition

Concussion has been shown to negatively affect cognitive abilities such as short-term memory (Hylin et al., 2013; Mayers, 2013; Yoo et al., 2018), long-term memory (Mayers, 2013; Ozen et al., 2013), prospective memory (Lajeunesse et al., 2019) and working memory (Gosselin et al., 2012; Li et al., 2016; Keightley et al., 2014; Sicard et al., 2018), as well as inhibitory control (Ho et al., 2018; Matthews et al., 2011; McGowan et al., 2019; Moore et al., 2014), and cognitive flexibility (Ellemberg et al., 2007; Hume et al., 2017; McGowan et al., 2018).

1.3.1 Memory

1.3.1.1 Short-Term Memory

The division of memory into short-term and long-term dates to Atkinson and Shiffrin's (1968), modal model of memory which suggests that information passes through

STM and if rehearsed, will be transferred to LTM, and therefore impairments to STM will negatively affect one's ability to store new information in LTM and consequently, disrupting daily functioning, mental health, and quality of life. For these reasons, efficient STM functioning is important for sporting prowess, with Hudac et al. (2018) suggesting working memory comprises the capacity to retain short-term information and to be integrated with high-order cognitive processing for planning and executing functions that are critical for effective cognitive and athletic activities.

The most popular method of assessing verbal STM is using digit-span forward tasks (Baddeley, 1966; Banken, 1985). This procedure can be administered face-to-face whereby the researcher reads out a sequence of digits (between 1-9), gradually increasing the number of digits per sequence and the participant recites them back in the same order. This differs from digit-span backward tasks which requires participants to produce the number sequence in reverse order and is used as a measure of working memory (Lefebvre et al., 2005). The digit-span tests have been shown to have adequate reliability and validity (The Psychological Corporation, 1997) and are sub-tests of the Wechsler Memory Scale III (WMS-III; Wechsler, 1997). Computer versions have also been developed to eliminate the investigator effects and to ensure tasks are accessible remotely. Yoo et al. (2018) attempted to explore blood-brain barrier disruption in those with post-concussion syndrome (PCS), with a digit-span forward task utilised as a task of STM. It was reported that increased blood-brain barrier disruption was higher in those that performed moderately or atypically on the digit-span forward test as opposed to those with average or good performance on the task. This provides good evidence that physical changes in the brain following concussion have a negative impact on digit-span tasks associated with short-term memory and supports its use as a neuropsychological assessment in this demographic (Meek et al., 2020; Moroni & Belin, 2020).

As well as the digit-span forward test, another sub-test of the WMS-III designed to assess short-term memory is the Verbal Paired Associates I (VPA-I with VPA-II measuring long-term memory), both administered verbally by the researcher. The VPA-I requires that the examiner to first read a list of eight word-pairs (e.g. Truck-Arrow, Insect-Acorn), and immediately after completion, the examiner reads one word from one of the pairs, and the participant's task is to respond what other word was paired with that word (e.g. when researcher reads "Truck", participant should respond "Arrow"). Terry et al. (2015) utilised this type of test to examine long-term impairments to cognition in former high school American football players that had suffered a minimum of two concussions whilst playing in that period. fMRI data from this study revealed that during a VPA task, non-concussed participants showed greater activation in several left hemisphere regions, including the middle frontal gyrus, inferior frontal gyrus, the orbitofrontal cortex, the planum temporale, the angular gyrus, and the supramarginal gyrus. These regions are included in the "levels-of-processing" model of language functioning (Craik & Lockhart 1972), which suggests that encoding more complex information requires additional cortical resources and therefore increases retention. The encoding of more complex verbal information has previously been associated with increased BOLD signal in the left inferior frontal, left prefrontal, left inferior parietal, middle temporal, and right supramarginal regions (Bonner-Jackson et al., 2007; Henson et al., 2005). These results suggest that concussed individuals may have subtle underlying changes in their verbal memory encoding system that limits them from accessing higher-order semantic networks. For instance, the control group may have used verbally mediated encoding strategies to a greater extent than the concussed group. This pattern of hypoactivation related to concussion history is consistent with other functional imaging studies examining the long-term effects of concussion several years after the injury (Ford et al., 2013; Monti et al., 2013). Therefore, it could be that Digit-Span Forward tasks assess transient effects of concussion, whereas VPA-I measures long-term effects, and therefore it is advantageous to utilise both simultaneously.

1.3.1.2 Long-Term Memory

VPA-I has dual functions. In addition to being a measure of STM, it can also be considered a learning task (Andrews, 2019). The VPA-II sub-test of the WMS-III that measures LTM, is advised to be carried out 25-35 minutes after the completion of the VPA-I. In the VPA-II, aimed to measure learning, participants' free recall or recognition of the eight word-pairs from the VPA-I are used as a measure of LTM. First, the participant is asked to repeat what they remember from the eight word-pairs. Then, in the recognition task the participant has to recognise the 8 VPA-I word-pairs among a total 24 word-pairs. Due to the 25-35-minute delay between the two tests, VPA-II is a measure of long-term memory. Little research has been conducted into how LTM is impacted following concussion and therefore this gap in the literature needs to be addressed using VPA-II as a measure.

1.3.1.3 Prospective Memory

Prospective memory is defined as either remembering to do something at a particular time in the future or as the timely execution of a previously formed intention (Kvavilashvili & Ellis, 1996). Prospective memory is commonly categorised by time-based and event-based tasks (Einstein & McDaniel, 1990). Time-based tasks require individuals to perform a specific task or action at a certain time or after a certain period has elapsed. Event-based tasks require the performance of a task or action when an external cue is present. Successful prospective memory performance is a complex process involving numerous stages and cognitive operations (Tay et al., 2010). The content of a delayed intention first needs to be formed, encoded, and retained until the start of the period the intention may be acted on and then retrieved at the appropriate time for the realisation of the intention and subsequently the intended action is initiated and executed (Ellis, 1996). Based on this assumption, prospective memory is an invaluable cognitive function for athletes, when they require to undergo time-based and event-based tasks such as changing tactics within a game or at a particular time. Beyond sport, it is clearly critical and instrumental for everyday activities and living such as household tasks like switching lights off, catching a train at a particular time, taking prescribed medication, or attending appointments.

Lajeunesse et al. (2019) examined the impact of concussion on prospective memory using the Ecological Test of Prospective Memory (TEMP) which consists of 10 event-based and 5 time-based tasks. Twenty post-concussed participants were compared with 15 control participants, showing that the post-concussed group displayed difficulties in learning the content of intentions, retrieving these intentions in the time-based condition, and recalled the associated actions in both the event-based and time-based conditions. These findings should be inferred with caution as the sample size was quite small, and the likelihood that post-concussed participants that were willing to take part may have been experiencing more persisting post-concussion symptoms, which could have exacerbated prospective memory deficits on the TEMP. Nevertheless, there is still value in finding evidence of persisting post-concussion symptoms accompanied by poorer prospective memory, and therefore further research should aim to incorporate event-based and time-based tasks when assessing post-concussed participants.

Whilst TEMP can be considered a good measure of prospective memory, an alternative test is the Royal Prince Alfred (RPA) Prospective Memory Test (Radford et al., 2011). The test uses real life items and contains event-based and time-based tasks measuring both short-term and long-term (Radford et al., 2011). A main benefit of using the RPA is the flexibility for the examiner to choose the tasks that are relevant to the project design and that the researcher can include other measures that are part of a clinical battery. Being able to measure both short-term and long-term measures of event-based and time-based prospective memory makes the RPA a robust method of assessing prospective memory within people who have sustained concussion and will be used in this project.

1.3.2 Executive Function

1.3.2.1 Working Memory

Working memory refers to the storage and manipulation of information held in STM while the person is completing a second cognitive task (Baddeley & Hitch, 1974), during everyday tasks such as problem-solving, planning, organisation, or self-monitoring. Working memory is deemed important for athletic performance, with it being necessary for competing athletes to focus attention and process task-relevant information during distracting events to ensure optimal performance and physical safety (Mayers et al., 2011). In addition, the ability to manipulate information in this way is also necessary in our daily functioning. Sicard et al. (2018) used a matched pairs design of 196 participants to assess the cognitive outcomes of athletes following sport-related concussion. All participants completed a computerised test called the Cogstate battery, which is frequently used to assess cognitive functions at baseline and up to several months following concussion during both the acute phase (Gardner et al., 2012; Louey et al., 2014; Makdissi et al., 2010) and the chronic phase of injury (Chen et al., 2007; Sicard et al., 2019). The battery provides measures of processing speed, attention, visual learning, and visual working memory. Traditionally, the Cogstate battery has used a 1-back condition of the n-back task (a working memory test). However, the researchers added a 2-back version of the test to increase cognitive load, with evidence of 1-back ceiling effects (Jaeggi et al., 2010).

As expected, participants of the post-concussed group recorded longer reaction times and poorer accuracy during both conditions than the control group. Additionally, it was found that post-concussed female participants responded significantly slower than post-concussed male participants for the 2-back task. With a good sample size of equal male and female athletes that have sustained concussion and healthy controls, this work supports previous claims that concussion has a negative influence on working memory (Keightley et al., 2014; Ozen et al., 2013). Post-concussed participants struggled to maintain the increased cognitive load during both n-back tasks. It is noteworthy that the sex differences observed only emerged in the 2-back task that the researchers included, whereby this condition is not commonly used in the Cogstate battery. From this, the work of Sicard et al. (2018) provides further evidence of impaired working memory following concussion, which is key for optimal performance in sport (Kimura & Matsuura, 2020). This study also indicates that the 2-back task is perhaps a more efficient tool for assessing working memory post-concussion than the 1-back task that the Cogstate battery uses at present. With post-concussed athletes displaying difficulty with the increasing cognitive load, this project uses a 3-back task to see how well this demographic cope compared with controls.

As mentioned earlier, the digit-span forward test assesses verbal STM (Meek et al., 2020; Moroni & Belin, 2020), while in the digit span backward task the stimuli are presented in the same manner, but the participant's task is to recite the numbers in the opposite order to which they were presented. The reversing procedure is an additional task to the act of storing the digits, which entails the spatial rearrangement of the read-out digits, requiring working memory processing. Guskiewicz et al. (2001) used a neurocognitive battery, including the digit span backward task with 72 healthy athletes, all completing a baseline assessment battery at the start of the season. Thirty-six of these participants had sustained concussion during that season and were assessed post-injury at three occasions: one-day, three-days and five-days. Analysis revealed that performance on the digit-span backward task was significantly lower on day 1 post-injury compared to baseline scores, however day 3 and day

5 scores suggest a logical steady return to baseline scores. While the authors argue this finding is evidence for concussion having a significant impact on working memory, at least in the 24-hour period following concussion, it is difficult to account for practice effects here. The reason is that there might be natural recovery in the days following injury, helping the neurocognitive functioning returning to baseline, however, it could also be due to task improvement as participants completed the same tasks in a short period of time and perhaps there is a learning effect that is masking any long-term negative consequence of concussion. Therefore, this project attempts to assess post-concussed participants at a more infrequent interval of six months to alleviate the chance of practice effects and determine whether concussion has a long-term negative influence on working memory.

Another psychological test that derived from the digit-span task is the Corsi block test (Corsi, 1972) that assesses visuo-spatial working memory. In this test, the examiner taps a sequence of up to nine separate blocks on a board and the participant is asked to remember and repeat the sequence either in the same order as the examiner or in reverse order. The test usually starts with only two blocks that gradually increases until the participant cannot complete the task. This measure is known as Corsi span, with the average forward span being between 5 and 6 for forward span (Kessels et al., 2000). As the test has often been used with patients exhibiting memory loss, or testing brain damaged patients, its use with post-concussed participants in psychological research is conventional. Tapper et al. (2017) are among researchers that have used Corsi block test when assessing executive function impairments, such as working memory, in those that have sustained concussion. The study involved 29 university ice hockey players, 18 of which had a history of concussion (9 with history of one concussion, 7 with two previous concussions and 2 with three previous concussions, which occurred 2-98 months prior to study participation) with the other 11 acting as controls. Participants completed two tests of visuospatial working memory which included Corsi block test, and an auditory tone discrimination task, individually and simultaneously. There was no difference in Corsi span and auditory tone discrimination accuracy when these tasks were performed individually, however, athletes that had sustained concussion previously had a significantly worse performance on the tone discrimination task in the dual-task condition. This highlights the chronic deficits in working memory in those that had sustained concussion when cognitive resources were stretched. Athletes' cognitive resources are constantly stretched during competition to reach optimal performance. If cognitive ability is impaired this could have potentially negative impacts performance on and the social factors that accompany it, regarding poorer mental health. Therefore, it is important to assess working memory performance in post-concussed athletes against those that have not sustained concussion, and Corsi block test is a viable tool alongside n-back and Digit-Span Backwards.

1.3.2.2 Inhibitory Control

Another executive function is inhibitory control, which involves being able to control one's attention, behaviour, and thoughts to override a strong internal predisposition and instead selecting to do what is the more appropriate action (Diamond, 2013). Those with impaired inhibitory control are typically impulsive to environmental stimuli, and therefore inhibition makes it possible to choose how to react in given situations. Similar to working memory, well-functioning inhibitory control is key to daily functioning, and is largely associated with successful sporting performance (Vestberg et al., 2012), and with evidence that this can be impaired following concussion (McGowan et al., 2019; Moore et al., 2014), inspection is warranted.

Matthews et al., (2011) assessed 27 post-concussed participants using the stop-signal task (Logan & Cowan, 1984) alongside fMRI scanning to measure impaired inhibitory control to identify brain changes during the task. The Stop Signal task consisted of participants viewing “X” and “O” stimuli, which would act as the “go” stimulus with participants required to click corresponding letters on the keyboard. For 25% of the trials these visual stimuli were followed by an auditory stimulus, which would act as the “stop” trials. Participants were instructed to respond as quickly and accurately as possible, and the 75% of “go” trials would create a dominant response for participants. The ability to inhibit to respond on the “stop” trials, was of interest. The stop signal delay (SSD) was adjusted on a trial-by-trial basis, using staircase tracking algorithms, to maintain stop success at 50%. Two separate staircase trackers were defined, one for stop-systole trials, and one for stop-diastole. Participants were instructed not to wait for stop cues and to respond as quickly and accurately to the stimuli as possible. Stop signal reaction times (SSRTs), representing the internal response to the stop-signal, were calculated according to the integration method. The researchers grouped participants into those that had experienced loss of consciousness and those that had alterations to consciousness, with no differences in inhibitory control found between these groups. Despite the lack of significant findings, Matthews et al. (2011) present a sound method of assessing inhibitory control in post-concussed athletes and future studies should aim to incorporate a control group to investigate any differences when isolating history of concussion.

Iverson et al., (2003) used a task called ImPACT (Immediate Postconcussion Assessment and Cognitive Testing) to examine post-concussion cognitive effects. The battery includes a go/no-go task, similar to the stop-signal premise. However, go/no-go tasks may involve response selection as well as inhibition (Kalaska & Crammond, 1995), so may not be the best option for response inhibition, like stop-signal may be. Although the 41 post-concussed amateur athletes recorded poorer reaction time composite scores for the battery following concussion compared to their baseline scores, the fact that these tasks were merged to form a composite score of reaction time makes it difficult to isolate the go/no-go task. In this study the reaction time composite score comprised of the go/no-go task, a choice reaction time task, and a symbol matching task. Therefore, this provides further evidence of the negative impact that concussion has on inhibitory control and the use of a go/no-go task, or stop-signal task, to assess this, but highlights the need to analyse the results of this measure solely and not simultaneously with other similar tasks.

The Stroop test is another well-validated tool for assessing inhibitory control as the delay in reaction time between congruent and incongruent stimuli is measured. The basic task comes from the original Stroop test (Stroop, 1935) in which the participants are shown colour words that are written in the same ink colour as the colour word itself. For example, the word red may be written in red ink (congruent trials) or in a different ink colour to the colour word (incongruent trials) – e.g., red is written in blue ink. The participant has to report the colour of the ink rather than the colour the word represents. Stroop examines inhibition, as the congruent trials pertain a dominant response from the participant, whereas incongruent trials require the participant to inhibit this dominant response and to alter this response. Participants tend to make more errors and need longer time to respond at incongruent trials, demonstrating differences in inhibitory control between participants. It is thought that those that have sustained concussion will have impaired inhibitory control and therefore make more errors and respond in a longer amount of time to those that have not sustained concussion.

A most recent work by Lempke et al., (2021) adopted the Stroop test to examine the performance of concussed and non-concussed drivers. Their analysis of 14 post-concussed patients and 14 healthy controls found a significant positive correlation between Stroop reaction time and stoplight reaction time in the driving simulation, compared with the control group that showed no associations. This finding demonstrates a reduction in inhibitory control in the post-concussed group through increased time taken to respond to incongruent stimuli on the Stroop test and reacting to the stoplight in the driving simulation. The authors conclude that this impairment to inhibitory control can be detrimental to driving performance. While this work aimed to understand the impact of the impairment to inhibition in driving conditions, this conclusion can still be applied to other areas of life, including sporting performance, and increased injury risk due to impaired inhibitory control. Additionally, a reduction in inhibitory control could also reduce general sporting performance which could in turn lead to athletes losing their positions in their teams and exacerbating mental health symptoms and reduced quality of life. Therefore, Stop-Signal and Stroop tasks will be utilised to explore inhibitory control in post-concussed athletes.

1.3.2.3 Cognitive Flexibility

A third executive function is Cognitive flexibility that builds on working memory and inhibitory control (Davidson et al., 2006) and involves the ability to adjust to changed demands or priorities (Diamond, 2013) and switch attention when necessary. To adjust to changed demands, individuals must inhibit the natural response of continuing the present task and load into working memory the new task to carry it out. This ability to inhibit the dominant response and activate working memory to switch between tasks is what is known as cognitive flexibility (Diamond, 2013). A type of switching involves continuing focusing on the same dimension, the local aspect of the stimuli, but reversing the stimulus-response mappings (Diamond, 2013) which is referred to as reversal or within-dimension switching (Kendler & Kendler, 1959; Kendler et al., 1972) and is a technique that has been used when assessing concussion sufferers.

Ellemberg et al., (2007) were among the first researchers to investigate cognitive flexibility in people with concussion. Their sample consisted of 22 female university-level soccer players, ten of which had sustained sport-related concussion, six to eight months prior to the study. Participants completed an adapted version of the Stroop test as quickly and accurately as possible, which showed that the post-concussed athletes were 1.5 times slower on flexibility components of the adapted task compared to the healthy athletes. While this study has a small sample size, the findings are supported by similar research on former rugby players (Hume et al., 2017). Hume et al. (2017) recruited 366 participants in total in their study measuring differences between former rugby and non-contact-sport players. As expected by the researchers, the rugby group performed worse on the cognitive flexibility Switching Attention Task (SAT) compared to the non-contact-sport players, with evidence that those that display cognitive impairments following concussion were more likely to have engaged in contact sports (Sone et al., 2018). Strengthening this point, it was also found that, regardless of sport, players who self-reported one or more lifetime concussions, had worse scores on cognitive flexibility than players who reported zero lifetime concussions. From this, the work of Ellemberg et al. (2007) and Hume et al. (2017) highlight the appropriate use of switching tasks when assessing cognitive flexibility in athletes that recall concussion with suggestions that this can be impaired in this group.

Hume et al. (2017) utilised an SAT which is a measure of ability to shift from one instruction to another, as quickly and accurately as possible. Their participants were instructed to match geometric objects by shape or by colour. Three figures appear on the screen, one on top and two on the bottom. The top figure is either a square or a circle. The bottom figures are a square and a circle. The figures are either red or blue and are mixed randomly. The participant is asked to match one of the bottom figures to the top figure. The rules change at random, whether matching the figures by shape or by colour. While SATs are well-validated assessments of cognitive flexibility, the Local-Global switching task is perhaps more relevant to athletes, as they continuously attend to local and global stimuli, and the ability to switch this appropriately is associated with increased performance (Montuori et al., 2019). This test uses a similar technique whereby tasks randomly switch between participants requiring processing either local and global stimuli, assessing their ability to switch between tasks and therefore their cognitive flexibility. For example, stimuli of letters made up of smaller letters could be presented to participants across a series of trials, with the task of identifying "A" or "H" as a "local" or "global" stimulus. That is, whether the letter "A" or "H" is present as a series of smaller letters to produce a large non-target letter (local response) or if the target letters are present as a large letter produced by a series of smaller non-target letters (global response).

Karr et al., (2014) assessed the long-term outcomes on executive function following concussion using a local-global task to measure cognitive flexibility. One-hundred-and-thirty-eight participants were involved in the ordinal logistic regression analyses that revealed the local-global task predicted the number of past concussions athletes had had. Therefore, switching tasks, like local-global appear to be more sensitive at detecting concussion group differences as well as impairment in attentional processing.

Another popular switching task that has been utilised when assessing post-concussed populations is the Trail Making Task (TMT; Reitan, 1955). TMT consists of two parts (A & B) in which the participant connects 25 circles, each containing a number or a letter as quickly as possible while maintaining accuracy (Arnett & Labovitz, 1995). The first part of the task, TMT(A), participants connect circles that only contain numbers 1-25, to provide a baseline score whereas the second part, TMT(B), acts as the switching task where participants alternate between connecting a series of numbers and letters. That is, the participants start with the number "1" and connects it to the letter "A" which connects to number "2" and then the letter "B", and so on until number "13" concludes the test as the twenty-fifth target. TMT has been used to assess cognitive flexibility in post-concussed athletes (Wilmoth et al., 2019) with it suggested that the test can identify cognitive impairment in dementia (Cahn et al., 1995) and therefore validates its use for investigating concussion affects. However, there is contradicting evidence of the use of TMT within this sample with some studies finding that concussion history does not negatively impact trail making task performance (Fasoranti et al., 2020). Having said that, this study involved a small sample of only 50 participants and the analysis technique makes it difficult to conclude that the differences between the groups is due to concussion or other co-occurring variables. In addition, there are studies that have found post-concussed participants to respond slower on TMT(A) and no differences with TMT(B) (Bryk et al., 2020) as well as TMT(A) performance negatively affected across time-points whereas TMT(B) performance was not (Wilmoth et al., 2019). Therefore, perhaps this test should be used with caution with post-concussed populations and other switching tasks like local-global ought to be utilised alongside TMT when investigating cognitive flexibility.

1.4 Quality of Life

Following a concussion there is evidence of mental health decline (Pryor et al., 2016; Walker & Marchant, 2020) and impaired cognition (Matthews et al., 2011; Lempke et al., 2021; Yoo et al., 2018) as well as a decline in quality of life (Gard et al., 2020). It is plausible to suggest an interaction between impaired cognition and lower quality of life, (e.g., struggling to complete daily tasks, possible change in employment status), in addition to not being able to compete at a performance level that one once could, which may negatively impact both mental health and quality of life.

Voormolen et al. (2019) were interested in the association between post-concussion symptoms (PCS) and health-related quality of life following concussion. In that study, the PCS referred to the existence of a cluster of post-concussion symptoms persisting for over three months after the concussive event (Hiploylee et al., 2017). The PCS was recorded using the Rivermead post-concussion symptoms questionnaire (King et al., 1995) and quality of life was assessed using the Health-Related Quality of Life Short Form-36 (SF-36; Ware et al., 1994). The SF-36 has been validated in mTBI populations, demonstrating good internal consistency and validity (Diaz et al., 2012; Guilfoyle et al., 2010) and is therefore the most used health-related quality of life tool in mTBI research (Polinder et al., 2015). Voormolen et al.'s (2019) analysis revealed that participants with PCS had significantly lower scores on SF-36, indicating a link between concussion and a decline in quality of life. It should also be noted that one domain of the SF-36 includes bodily pain, with those not displaying PCS symptoms recording much higher scores on this domain, indicative of higher quality of life, and therefore less physical pain, and that these findings have been reported elsewhere (Gard et al., 2020). These findings can be supported by Ponsford et al. (2019) who were interested in the persistence of post-concussion symptoms following a concussive event in adults. The authors found that quality of life scores, recorded using SF-12 (Ware et al., 1996), were significantly correlated with post-concussion symptoms. Not only does this finding further highlight the association between concussive events and lower quality of life, but it also promotes the use of the shorter SF-12 version when investigating quality of life in post-concussed samples (Asselstine et al., 2020; Brett et al., 2020; Weber et al., 2019).

A limitation of the SF-12 is that it may be a generic measure of quality of life, with no intended demographic. As athletes are at elevated risk of sustaining concussion, perhaps a tool more focused on aspects of quality of life that are important to athletes would be more appropriate. Hence the Athlete Life Quality Scale (ALQS; Gentner, 2004) was developed to investigate quality of life in athletes. Although this five-factor tool includes general life satisfaction, physical satisfaction, team/sport satisfaction, primary social satisfaction, and recovery/social satisfaction, to our knowledge this measure is yet to be used with post-concussed samples. This may be unexpected with sub-scales such as physical satisfaction perhaps related to the link between pain and reduced quality of life (Ponsford et al., 2019), and recovery satisfaction being negatively related to abstaining from competition and hence losing their position to a teammate (Smith & Milliner, 1994), both leading to other social factors influencing general life satisfaction. This gap could be indicative of concussion and quality of life research being a relatively new topic rather than a reflection on the ALQS' use with this sample. Therefore, as a validated measure with Cronbach's Alpha recordings of 0.83 (Gentner, 2004), the ALQS should be used in juncture with the SF-12 to determine its usage with post-concussed samples.

1.5 Attitudes and misconceptions towards concussion in sport

With the dangers of concussion becoming a well-studied topic of exploration within academia, it is necessary for this wealth of knowledge to be transferred to and applied in real life (i.e. sport activities). There is contradicting evidence of informed attitudes towards concussion in sport (Pearce et al., 2017), with some suggesting sportspeople having sufficient concussion knowledge and safe attitudes (Kraak et al., 2019) while other studies indicating the opposite (Hutchinson et al., 2019; Leahy et al., 2020). Although there are discrepancies in the literature with regards to whether athletes possess poor knowledge and attitudes of concussion, further exploration is warranted to see whether sportspeople who have a history of concussion are more knowledgeable about the real effects of concussion and also to seek deeper understanding of what athletes believe what would increase the knowledge in the field of the sport.

There have been studies investigating the reasons behind the lack of knowledge in sport about concussion effects. Hutchinson et al., (2019) were interested in the potential poor attitudes and misconceptions of ice hockey players across various levels of competition. Sixty-one male ice hockey players completed the Rosenbaum Concussion Knowledge and

Attitudes Survey and reviewed a series of statements to assess knowledge, attitudes, and misconceptions of concussion. Interestingly, level of competition and concussion history had no impact on knowledge or attitudes of the players, whereby you would expect higher level of competition and those that have sustained concussion to have better knowledge and safer attitudes. However, playing experience was significantly and positively correlated with concussion knowledge and attitude, suggesting that the longer that athletes play, the better is their understanding of concussion and safer attitudes regarding sustaining one. Statements identified common misconceptions and areas of accurate knowledge of concussion symptomology, which suggests that male ice hockey players may have a better knowledge of concussion to the general UK public. Therefore, the authors concluded that while there was good knowledge of loss of consciousness and correct symptom management, there are alarmingly unsafe attitudes regarding aspects of concussion, which could threaten player safety as well as short-term and long-term health.

Another study looking at the athletes' attitude to safe sport shows that unsafe attitudes towards concussion may be due to athletes' failure to adhere to return-to-play protocols once their symptoms subside (Weber & Edwards, 2012). Additionally, it has been reported that over a quarter of concussions in the National Hockey League (28.4% in 2011-12 season) were due to illegal incidents (Donaldson et al., 2013). While it may be that these illegal incidents were genuine attempts of fair play that failed, it is also possible that the competitive nature of professional athletes coupled with possessing unsafe attitudes towards concussion could have led to gamesmanship on the part of the offending player (Kavussanu & Ring, 2021; Sage et al., 2006).

Hutchinson et al. (2019) utilised the Rosenbaum Concussion Knowledge and Attitudes Survey to assess the sportspeople's knowledge and attitudes of concussion, and this quantitative technique is adopted elsewhere (Kraak et al., 2019; Leahy et al., 2020).

However, when it comes to knowledge and attitudes, questionnaires pose validity issues. In contrast, to obtain first-hand information of athletes' beliefs towards concussion and its' real effects on athletes, the use of a qualitative approach is more suitable as they can gather deeper, more personal and lived experiences from athletes. Thematic analysis (TA; Braun & Clarke, 2019) is popular when analysing interviews as it provides insight into identifying and organising patterns of meaning (Braun & Clarke, 2019). Therefore, in the interests of exploring sportspeople's attitudes towards and knowledge of concussion, one-to-one semi-structured interviews were conducted. The data were analysed with a TA analysis technique, which was deemed to be more appropriate than quantitative methods such as using Rosenbaum Concussion Knowledge and Attitudes Survey.

Based on past research, sportspeople may still possess poor attitudes towards concussion and have misconceptions of what they are, despite the growing academic knowledge about concussion and its adverse effects on people's lives. Bridging this gap warrants exploration utilising a qualitative approach.

1.6 Data collection in concussion research

Many studies investigating concussion use a self-report method for concussion history due to practical difficulties with obtaining evidence of official and clinical diagnosis. Consequently, it is suggested that as many as 50% of concussions go unreported (Harmon et al., 2013), as well as the likelihood of athletes not disclosing concussive events in the fear of being side-lined and risking losing their position in the team (Smith & Milliner, 1994). Therefore, the use of self-report might have the potential for misclassification in these studies. As an alternative to self-report, more objective measures have been designed. For example, the Post-Concussion Symptom Scale (PCSS; Lovell, 2006) is a widely used instrument for measuring concussive symptoms. The PCSS contains 22 items meant to measure severity of symptoms in the acute phase of recovery from concussion (Lovell & Collins, 1998). However, some of the symptoms may not necessarily be related to concussion only; so that even non-injured athletes may report symptoms at baseline. As an example, a study by Iverson et al. (2003) showed that the mean symptom score for non-injured athletes was 5.8 despite having no concussion history, while at the same time they found that 76% of athletes scored 6 or less, with a large portion scoring 0 (40.5%). With this information, other researchers recommended a cut off score of <7 before allowing athletes to return to play (Lau et al., 2011; Sicard et al., 2018), based on evidence that premature return to play is a mechanism for repeated SRC (Tarzi et al., 2020). With the knowledge that most non-injured will score <7 on the PCSS (Iverson et al., 2003) and available research that suggests only post-concussed athletes with a score ≥7 to be allowed to return to play, it seems plausible that this can be considered a cut-off score of concussion. If an athlete is deemed not fit to return to play based on their PCSS scores being ≥7, then this suggests that they are displaying post-concussive symptoms indicative of concussion. Therefore, the cut-off score of ≥7 will be used in this project to conceptualise concussion.

1.7 Difficulties in measuring physical pain

This project can be viewed as ambitious, given that not only are there substantial difficulties in measuring concussion as previously highlighted, but there are also obstacles that present themselves when recording levels of physical pain too. For example, physical pain can only be a subjective measure, by self-reporting the level of physical pain that one is experiencing. From this, pain thresholds act as a confound, as what is classed as very painful to one person may not be perceived as painful to another. This is vitally important when assessing athletes, as there is evidence that pain tolerances are higher in athletes (Tesarz et al., 2012; Ryan & Kovacic, 1966) as they are used to continuing through the pain barrier while competing (Atkinson, 2008; Cook et al., 1997; Deroche et al., 2011).

Numeric Rating Scales are commonplace within (Walker & Marchant, 2020; Walker & McKay, 2022) and outside (Nimbley et al., 2023) of sport. The most popular being the NRS-11 (Downie et al., 1978) which asks for participants to report the level of physical pain experienced in the past week, ranging from zero to ten. Downie et al. (1978) also provide descriptors which aid participants interpretation of pain (0 = no pain, 1-3 = mild pain, 4-6 = moderate pain, 7-10 severe pain). This measure is limited by attempting to capture an insight of physical pain across the past week. For example, a footballer completing this survey on a Friday may have experienced a 7/10 the previous Saturday when they were competing, that has since reduced to a 1/10. This footballer may now be unsure as to what number to report as both their 1/10 and 7/10 levels of pain were within the last week, and they will probably compromise and report 4/10. Although there is the argument that this is counterbalanced across athletes, we are still not obtaining accurate accounts of physical pain.

The type of sport that athletes compete in should also be considered as Assa et al. (2018) found that strength athletes had higher heat-pain thresholds than endurance athletes and controls. It was also found that endurance athletes had a higher heat-pain tolerance than strength athletes and controls (Assa et al., 2018). These two findings show that regardless of sport type, athletes have both higher pain thresholds and tolerance than non-athletes, likely due to their consistent exposure while competing (Atkinson, 2008; Cook et al., 1997; Deroche et al., 2011). Therefore, this should be considered when comparing physical pain scores between athletes and non-athletes as it is likely athletes can withstand higher levels of physical pain and this may manifest itself in lower reporting. Assa et al. (2018) also demonstrate how type of sport is an important consideration when assessing pain in athletes, as their findings are reflective of what is commonplace in their sports, in that endurance-based athletes have improved pain inhibition and strength-based athletes have reduced pain sensitivity, both of which are likely to lead to lower scores on pain questionnaires.

Athletes may also have motive to not fully disclose their physical pain, due to the implications this may have on their sport (Druckman & Rothschild, 2018). Reporting high levels of physical pain to their coach may result in not being selected to compete, and therefore the athlete is motivated to under-report their physical pain that they are experiencing. Liston et al. (2018) also reports a "head-strong" culture that may contribute to athletes not wanting to be perceived as weak (Wilson et al., 2021) due to the sporting culture they are immersed in. This can also lead to the under-reporting of physical pain and therefore, this should always be considered when investigating the physical pain of athletes as they are likely to under-report their pain in fear of being perceived as weak, and/or jeopardising their chance of selection.

1.8 Conclusion

A summary review of past research presented above shows evidence of concussion having a negative impact on mental health, such as depressive symptoms (Pryor et al., 2016) and anxiety symptoms (Yang et al., 2015), as well as cognitive impairments such as short-term memory (Hylin et al., 2013; Mayers, 2013), long-term memory (Mayers, 2013; Ozen et al., 2013), working memory (Gosselin et al., 2012; Li et al., 2016; Sicard et al., 2018), prospective memory (Lajeunesse et al., 2019), inhibitory control (Ho et al., McGowan et al., 2019; Moore et al., 2014), and cognitive flexibility (Hume et al., 2017; McGowan et al., 2018). Given that the above could be consequences of concussion, it is unsurprising to see a link between concussion and reduced quality of life (Gard et al., 2020), and therefore these three main outcomes warrant simultaneous exploration, which is a novel approach in this area. Additionally, exploring potential poor attitudes and misconceptions of concussion in sport is key for identifying current knowledge base and attitudes towards concussion. This could provide a basis for engaging with athletes to alleviate any potential negative attitudes or misconceptions in sport, and therefore increasing safety among athletes.

Chapter 2: Methodology

2.1 Studies 1-5

2.1.1 Participants

The study's population consisted of a convenience sample of 212 participants (Male, *n* = 95, *M* = 24.29, *SD* = 5.55; Female, *n* = 117, *M* = 21.09, *SD* = 4.84). Athletes and non-athletes were utilised and participants' SRC history as well as its type (concussion sustained away from sport) were recorded. Athletes were self-identified which is supported by Araújo and Scharhag (2016) that found minimal criteria to be defined as an athlete include training/performing in sport, registered for a team, and spending several hours per week engaging in sport. In addition to self-reported concussion/SRC history, the Post-Concussion Symptom Scale (PCSS; Lovell, 2006) was used to define whether the symptoms they had experienced were indicative of concussion/SRC, with a cut-off score of ≥ 7 indicating a concussion (Iverson et al., 2003; Lau et al., 2011; Sicard et al., 2018). Participants that reported having sustained concussion/SRC must have done so at least one month before taking part in the study, so not to exacerbate any symptoms. All post-concussed participants provided details of time elapsed since sustaining concussion and their recovery period. Those that had sustained multiple concussions did so for each concussion. Athletes that have no history of concussion were assessed to isolate confounding factors such as physical pain that may influence poorer mental health, impaired cognition, and reduced quality of life. A control sample of non-athletes was also collected to determine whether the physical and mental stressors of being an athlete results in the three outcomes mentioned above as opposed to this being due to head injury of which this group are so often exposed to. Many athletes came from universities in the North-West of England and surrounding universities as well as neighbouring sports clubs. Given the relative impact that physical fitness may have on cognition, data about their sport participation (level of participation, hours per week etc.) was also collected. It is noteworthy that given the outbreak of COVID-19 in the UK in spring 2020, information about other possible social factors were also incorporated (noted in GIQ).

2.1.2 Design

Cross-sectional between and within-subjects designs were utilised as all participants completed the same measures, whether they had sustained SRC, NSRC, or had no concussion history. Demographic variables were recorded in the General Information Questionnaire, providing details of participant characteristics. Dependent variables were mental health (depression, state-trait anxiety, affect), cognition (short-term memory, long-term memory, working memory, prospective memory, inhibitory control, cognitive flexibility), and quality of life. The questionnaires assessed their mental health such as depressive symptoms, anxiety symptoms, and positive/negative affect and their quality of life in both athletes and non-athletes. Both groups completed the same quality of life questionnaire. In addition, athletes also completed an athlete quality of life survey. A cognitive battery of various tasks assessed different areas of cognition, particularly executive function. The tasks provided measures of short-term memory, long-term memory, working memory, prospective memory, inhibitory control and cognitive flexibility.

2.1.3 Measures

General Information Questionnaire (GIQ)

This survey was designed to obtain relevant demographic variables from participants. Demographic variables are displayed in Figure 1.

Figure 1. Demographic variables that participants were asked in GIQ

Biological Sex	Age	Employment status	Receipt of UK's furlough scheme
Athlete status (self-identified)	Predominant sport	Level of participation (most recent/highest)	Hours per week participating in sport (before COVID-19 outbreak in the UK/in the past week)
Non-SRC/NSRC (physical) injury history in past 12 months (time since occurred/recovery time)	History of SRC (time since occurred/recovery time)	History of concussion away from sport (time since occurred/recovery time)	Physical pain experienced in the past week using an 11-point Likert scale
Average alcohol consumption (before COVID-19 outbreak in the UK/in the past week)	Whether they had ever tested positive for COVID-19 (time since occurred/recovery time)	Bereavement due to COVID-19	History of diagnosed mental health disorders (before/since COVID-19 outbreak in the UK)

Post-Concussion Symptom Scale (PCSS; Lovell, 2006 – Appendix H)

The PCSS was used to assess whether those that have reported sustaining concussion/SRC had done so. The questionnaire contained 22 items, enquiring about symptoms of concussion in respondents. Participants were required to report to what extent they experienced each symptom following the concussive event on a seven-point Likert scale (0-6), with '0' indicating participants did not experience said symptom while '1-6' indicated increasing severity. The sum of scores was calculated between 0-132, with a cut-off score of ≥7 indicative of an individual that experienced concussion/SRC (Iverson et al., 2003; Lau et al., 2011; Sicard et al., 2018).

Center for Epidemiological Studies Depression Scale (CESD; Radloff, 1977 – Appendix I)

Depressive symptoms were measured using CESD which is a 20-item questionnaire that measures the depressive symptoms experienced in the past week (e.g. I felt lonely; my sleep was disrupted; I felt sad; I felt that people disliked me etc.). A four-point scale was used to rank the responses; 0 to 3. 0 indicated that participants had experienced said symptoms 'rarely or none of the time' (less than once a week), 1 being 'some or a little of the time' (1-2 days a week), 2 being 'occasionally or a moderate amount of time' (3-4 days a week) and 3 being 'most or all of the time' (5-7 days a week). Items 4, 8, 12 and 16 were reverse scored due to the nature of the question. The sum of scores was calculated between 0 and 60, with a total score ≥ 16 highlighting that an individual may be experiencing some form of depression (Husaini et al., 1980). The higher the total score produced, the more severe level of depression.

State-Trait Anxiety Inventory (STAI; Speilberger et al., 1970 – Appendix J)

Anxiety was measured using STAI which is a 40-item questionnaire providing a measure of both state and trait anxiety (20 state anxiety and 20 trait anxiety). State anxiety questions and trait anxiety questions were presented as two distinct surveys, Y-1 and Y-2 as is commonly administered. The Y-1 State-Anxiety form evaluated how an individual felt at present or “at this moment” (I feel calm; I feel secure; I feel satisfied etc.) in reference to situations that could influence anxiety levels as opposed to the Y-2 Trait-Anxiety form that produced a measure of how the individual felt “generally”, although there is no time frame given here. The four responses for both questionnaires were ranked 1 to 4. For the Y-1 State-Anxiety form, 1 suggested ‘not at all’, 2 indicated ‘somewhat’, 3 indicated ‘moderately so’ and 4 indicated ‘very much so’. For the Y-2 Trait-Anxiety form, 1 suggested ‘almost never’, 2 indicated ‘sometimes’, 3 indicated ‘often’ and 4 indicated ‘almost always’. Numerous items were reverse coded in both forms based on the nature of the question. This resulted in a scoring range of 20-80 for both State-Anxiety and Trait-Anxiety with greater scores indicating higher anxiety levels.

Positive and Negative Affect Scale (PANAS; Watson et al., 1988 – Appendix K)

PANAS was used to assess participants emotional response to everyday life. The 20-item short-form was utilised with 10 emotions measuring positive affect with the remaining examining negative affect. Like the CESD, PANAS requires participants to indicate how they have felt over the past week. A five-point Likert scale was used to rank responses; 1-5. One indicates that a participant has felt that emotion ‘very slightly or not at all’, 2 being ‘a little’, 3 being ‘moderately, 4 being ‘quite a bit’ and 5 ‘extremely’. The sum of scores was then calculated between 10 and 50 for both positive and negative affect, with greater scores indicating greater levels of positive/negative affect.

Royal Prince Alfred Prospective Memory Test (RPA-PMT; Radford et al., 2011 – Appendix L)

The RPA-PMT was used to record participants prospective memory capability. This test included four different measures, time-based, remembering to carry out an action after a certain period and event-based, remembering to carry out an action when an event occurs, as well as short-term and long-term for both. The short-term tasks were presented to participants at the beginning of the video call which were recorded during the session and the long-term tasks were presented at the end of the video call and were recorded up until a week after the session ended. Participants were asked at the beginning of the session to say the words “Ding, Ding, Ding” when they thought 15 minutes had elapsed. It was the responsibility of the participant to remember this without setting an alarm of any sort. Participants were also informed that they were not to stop what they were doing in the study, just to speak those words. The researcher recorded this during the video call with responses given between 15:00-15:59 on the researcher’s timer deemed correct. This acted as short-term, time-based assessment of prospective memory. The other instruction they were given was approximately half-way through the session there would be a break, and during this time they were to ask the researcher what the weather was like. This acted as short-term, event-based assessment of prospective memory. The break would last 5 minutes with the researcher once again recording this. Correct responses were those that asked the question specified within this period.

The long-term measures of prospective memory were introduced at the beginning of the video call. The researcher explained that they were going to ask them to do two more things for after the session was complete. The first of which was to email the researcher a rating after their next meal from 1-10. This acted as an event-based long-term prospective memory task, in which the researcher would score them 0 if participants did not do this, and 1 if they did. The second thing participants were asked was to request their debrief form (appendix C) including some explanation of their results, one week from the day they were participating. This acted as a time-based long-term prospective memory measure. Participants had until 23:59 on the day exactly one week from the day they participated to request this via email, scoring 1 if they remembered to do so, and 0 if they did not. For participants that did not request this, the debrief form was sent to the participant with their results on the eighth day following participation ensuring all participants were fully debriefed following the study.

Wechsler Memory Scale III – Verbal Paired Associates I/II (Wechsler, 1997 – Appendix M)

The Wechsler Memory Scale III (WMS-III) is a neuropsychological test designed to measure different memory function and originally includes seventeen different sub-tests. The two sub-tests used in this study were Verbal Paired Associates I (VPA-I) and II (VPA-II) which provided a second measure of short-term memory and long-term memory, respectively. These tests are typically administered verbally by the researcher in person. However, due to COVID-19 disruptions this was done over video call with each participant. Accuracy of recall were recorded in both sub-tests with a recognition factor also included in VPA-II.

Athlete Life Quality Scale (ALQS; Gentner, 2004 – Appendix N)

Two different measures of quality of life were administered. The first one was the ALQS which is a 15-item questionnaire assessing quality of life in athletes within a five-factor structure; general life satisfaction, physical satisfaction, team/sport satisfaction, primary social satisfaction, and recovery/social satisfaction. Responses were recorded on a seven-point Likert scale, 1-7. 1 indicated that a participant is ‘very dissatisfied’ with the aspect of life on the list whereas 2 indicated they are ‘dissatisfied’, 3 ‘slightly dissatisfied’, 4 ‘neutral/undecided’, 5 ‘slightly satisfied’, 6 ‘satisfied’ and 7 ‘very satisfied’. The sum of scores were then calculated between 15 and 105, with greater scores highlighting greater life satisfaction.

Health Related Quality of Life: SF-12 (SF-12; Ware et al., 1996 – Appendix O)

The second measure of quality of life was the SF-12. This questionnaire was included as the ALQS is specific to an athletic population, and with a non-athletic control in our sample, a generalised measure of quality of life was required. This questionnaire contains 12 items and required different levels of response from the participant. A variety of different question types required participants to respond on two, three, five and six-point Likert scales. These ranged from 'yes/no', 'yes, limited a lot/yes, limited a little/no, not limited at all', 'excellent/very good/good/fair/poor', 'not at all/a little bit/moderately/quite a bit/extremely' to 'all of the time/most of the time/a good bit of the time/some of the time/a little of the time/none of the time' when responding to different aspects of their health related quality of life. Four of the twelve items were reverse coded due to the nature of the question before the sum of scores was calculated between 0 and 36, with greater scores indicating better quality of life.

Working Memory

N-back task – The N-Back task consisted of one, two and three backloads respectively. Each task began with instructions explaining the task. For 1-back, this was to press "1" on the keyboard when the letter on-screen matches the letter previous or "2" if this did not match. The 2-back task was similar, however participants were to select "1" if the letter on-screen matched the letter two letters back and the 3-back task required the same action if the letter on-screen matched the letter three letters back. Visual instructions were given for each task indicating to participants which letters would be targets and non-targets and had the option to repeat this until they felt comfortable. A short practice task would follow this before the experimental task. Again, participants had the option to repeat this. The experimental task consisted of 20 letters of the alphabet excluding vowels and the letter "X". One cycle would comprise the tasks with these 20 stimuli selected at random, that is, the possibility of them all being displayed once, however it was possible for stimuli to be repeated so this was unlikely.

Each stimulus was presented for 500 m/s followed by a 3000 m/s response period. When a response had been recorded this prompted the next stimulus to be presented.

Digit-Span Backward task - participants would hear a series of numbers in each trial, and once the voice had finished, they were to input the numbers that had been read out, in the ***reverse order***. This ranged from 2-9 digits. Each level contained three trials before increasing by one digit, leaving 24 trials in the test. Although participants were instructed to complete this task as accurately and quickly as possible, there was an infinite response period that followed the audio.

Inhibitory Control

Stroop colour switching task - This test presented participants with written words of four different colours: green, blue, red, or yellow. The ink that these words were presented in also alternated between these four colours. The task for participants was to simply respond as to what the ink colour was, rather than the colour that the word is. That is, if the colour word was blue and the ink colour was red, then red would be the correct response. Participants had to press the G, B, R or Y keys on the keyboard to record their response. A graphic of this was maintained at the bottom of the screen throughout the trials. After the instructions, participants completed a short practice test. This included four trials ran through two cycles leaving eight trials in the practice. The trials consisted of colour word and ink pairings of green-green, yellow-blue, green-yellow and blue-red, which meant that 25% of the trials were congruent and 75% were incongruent. Trials were presented for a maximum of 5000 m/s or until responses were received, and this was followed by a 1000 m/s feedback screen. This would inform participants of their accuracy throughout the trials as well as their response time for the previous trial. The experimental task followed whereby all colour combinations were used, doubling the number of match trials, producing 20 different trials. This left 12 (60%) incongruent trials and 8 (40%) congruent trials. These were randomly selected through

6 cycles, with repetition after a reset possible, leaving 120 trials in the experimental task. The same timings were used as in the practice task.

Stop-Signal task – The task was to simply press the corresponding letter on the keyboard when presented with the stimulus, however, on some trials a tone would also be presented. It is on these trials where participants are to refrain from responding, displaying their inhibitory control. A practice block followed the instructions which included 21 trials, 16 were "go" trials whereby there was no auditory tone present and 5 were "stop" trials where audio stimulus was present, so to produce a dominant response during the go trials. Each trial would last 3000 m/s in which participants could respond. For go trials, the image would be shown for 1000 m/s before a 2000 m/s blank screen was displayed. For stop trials the same would occur, with a 250 m/s tone sounding within the 1000 m/s image window. Using a dynamic tracking procedure, incorrectly responding to a stop trial would increase the stop-signal tone delay by 50 m/s and correctly inhibiting this response to a stop trial would decrease the stop-signal tone delay by 50 m/s. These changes would start from the initial delay of 250 m/s, meaning that the tracking will converge on where participants are 50/50 on a particular tone delay. A 500 m/s fixation period would segregate each trial. Once completed, the experiment of 64 trials, 16 stop (25%) and 48 go (75%) began.

Cognitive Flexibility

Local-Global task – The task was simply to respond as quickly and accurately as possible whether the letter "A" or the letter "H" was present, by selecting the corresponding keys on the keyboard. This task is a switching task as sometimes the letters "A" and "H" would comprise a larger letter and alternatively other letters could comprise large "A" or "H" letters. Thus, shifting participants attention consistently between local and global focus. Participants were made aware that the possibility of being presented with either target letter was 50% and therefore "A" or "H" were present in each trial. Letters "L" and "T" were used at the local and global levels opposite to the targets “A” and “H”. Targets and trial locality were split evenly. Following the instructions screen, participants were displayed a fixation of 1000 m/s followed by the stimuli which was displayed for 150 m/s. Participants then had a 5000 m/s response window to record their answer as quickly and accurately as possible. When participants had responded within this window or when the time had elapsed, a feedback screen was displayed with how they performed on that trial which would be displayed for 1500 m/s. This window would provide an updated accuracy score through the trials as well as response time to the previous trial. There were sixteen trials in one cycle with the task including six cycles, totalling 96 trials.

Short-Term Memory

Digit-Span Forward task – participants would hear a series of numbers in each trial, and once the voice had finished, they were to input the numbers that had been read out, in the ***same order***. This ranged from 2-9 digits. Each level contained three trials before increasing by one digit, leaving 24 trials in the test. Although participants were instructed to complete this task as accurately and quickly as possible, there was an infinite response period that followed the audio.

2.1.4 Apparatus

E-Prime/E-Studio/E-Prime GO

E-Studio software from the E-prime suite (Psychology Software Tools, Pittsburgh, PA) was used to create six of the eight computerised cognitive tasks in the cognitive battery. The six E-Prime tasks assessed different areas of executive function including working memory, inhibitory control, and cognitive flexibility. Accuracy scores and reaction times were recorded for all tests. Due to the COVID-19 outbreak in the UK in spring 2020, these tests were converted to E-Prime GO files, ensuring participants could take part remotely.

Millisecond/Inquisit 4 & Pavlovia/Psychopy

Inquisit 4 (computer software) by Millisecond (2015) was utilised to conduct the Trail Making Task designed, like the Local-Global E-Prime task, to measure cognitive flexibility. Pre-pandemic, this would have been conducted on paper with the researcher. However, with the project adapting to a remote-based procedure, this computer task was selected. Inquisit 4 was appropriate as the task required participants to draw a line between different points on the screen, recording mistakes participants make, something that is not possible using E-Prime. Accuracy scores and time taken to complete the trails were recorded. Additionally, the test was readily available on the millisecond website, and well-validated with its usage in ample studies. Due to a departmental decision, the Millisecond license was replaced with the software Pavlovia (Peirce et al., 2019), using a Trail Making Task designed in Psychopy (Pierce, 2007) environment. This was built in January 2021 and used the same Excel co-ordinates as the millisecond/Inquisit version, replicating what participants had completed prior to this change. Participants completed a practice trial before each experimental trial, whereby accuracy scores and time taken to complete the trials recorded. Participants did not receive feedback in practice or experimental trials, rather the practice trials were utilised to ensure participants understood the task before the experimental trial began.

The TMT included two trails (A & B) whereby TMT(A) was simply to direct the cursor in numerical order from 1-25 as quickly and accurately as possible. TMT(B) was a switching task between numbers and letters. The task was still to select numbers in numerical order but also now to select letters in alphabetical order in between each number (1 – A – 2 – B etc.). This was again 25 items from 1-13 with the first twelve letters of the alphabet, A-L, amongst this. Accuracy was recorded by mistakes made and reaction time from total time taken to complete TMT(A) and TMT(B).

Psytoolkit

Like millisecond, psytoolkit (Stoet, 2010; 2017) was used to perform a computer task that E-Prime could not accomplish. This was the Corsi block test (Corsi, 1972) which required participants to view numerous square images that would flash on the screen in a sequence and then repeat the order in which they flashed using a mouse. The number of squares participants could remember correctly in correct order is referred to as block-load and participants reported this figure in the questionnaire in Qualtrics.

2.1.5 Procedure

All participants took part in the same testing conditions during the experiment. The study was separated into two parts, both of which were completed remotely. Initially participants were required to complete a series of questionnaires that recorded mental health symptoms and quality of life scores as well as four different computer tasks assessing different aspects of cognition (working memory and cognitive flexibility). Upon completion, on a separate day, participants would then attend a video call with the researcher whereby another four computer tasks were completed alongside tests that were verbally administered by the researcher assessing areas of cognition (short-term memory, long-term memory, prospective memory, working memory and inhibitory control). When participants approached the researcher with their intentions of taking part, a timeslot was agreed for the video call including the cognitive tasks. When this timeslot was agreed, the researcher could then send over the links to the questionnaires and cognitive tasks that the participant was required to complete before the video call. For this reason, the timeslot for the video call was agreed between participant and researcher so to give the participant enough time to complete these tests before the video call. This was typically a couple of days before the video call. Those that had not completed the questionnaires and computer tasks could not take part in the computer tasks over video call with the researcher.

Pre-video call assessments

The initial email to participants included instructions on how to complete this prior to the timeslot they had booked with the researcher, as well as a reminder of when this was. They were also given their subject number and session number that was required for all E-Prime tasks and would also be used again during the video call assessment. Attached to the email was an electronic copy of the participant information sheet (appendix A) as well as two hyperlinks numbered 1 and 2. The first link would take participants to the questionnaires embedded with computerised tasks in Qualtrics and the second link was their own personal participant data on Google Drive, for them to transfer their E-Prime data files once they had completed. E-prime saves data files onto the device the experiment was conducted on and therefore datafiles were saved on the participant's computer. Participants were informed that this session would take approximately one hour and advised to complete the tasks, all in one sitting, in a quiet environment.

Once deciding to begin, participants were presented an electronic copy of the participant information sheet on Qualtrics, identical to the one sent as an attachment in the original email. The next screen displayed the consent form (appendix B), whereby participants were required to provide informed consent with an option for not being allowed to proceed if this requirement was not satisfied. On this page, there was also an option to leave contact details for the researcher to contact participants six months after participating in the study with an invitation of taking part for a second time. Following this, participants created a unique ID that would be used to collate data from the different software that were used in the study. This would consist of six-digits and would comprise of the two digits of participants month of birth, followed by the last two digits of their year of birth followed by the first two digits of their postcode. An example was provided here to aid participants. All questionnaires in this project followed.

The first survey displayed was the GIQ, devised by the researchers to obtain demographic variables of participants, to group them in terms of athlete status and concussion history as well as controlling for other variables that could influence their performance in the study. This was followed by mental health questionnaires, CESD, STAI and PANAS, that measured depressive symptoms, state and trait anxiety symptoms and positive/negative affect, respectively. Participants that identified as athletes in the GIQ were then displayed the ALQS to measure quality of life in this demographic, with this omitted if participants responded as not qualifying as an athlete by the definition given. All participants were then shown the SF-12, to ensure all participants had at least one measure of quality of life. This was the final questionnaire in this series and computer tasks followed.

The next screen began with instructions on how to complete the Corsi Block Test, with a hyperlink opening another tab. This test typically takes 2-3 minutes and provides participants with their scores, Corsi Block-load, upon completion. Participants then navigated themselves back to the Qualtrics tab and typed in their score in the space provided. Similarly, the screen that followed provided instructions on how to complete the TMT (A&B) and included a hyperlink that opened a pavlovia tab. This session ended with two E-Prime tasks, as it was deemed fitting to prime participants on what to expect in the video call. This next screen included a hyperlink to a Google drive that consisted of two tasks, Local-Global and N-Back that were converted to E-Prime GO files by the researcher to make them remotely accessible, without participants requiring the E-Prime software. These were counterbalanced by the researcher. Upon completion, there were instructions provided on how to send data files back to the researcher including the second link provided in the original email that took participants to their own, individual data Google Drive. This would ensure participants can only view their own data files and did not have access to other participants' data. Once completed, the final screen on the Qualtrics survey informed participants of the end of this part of the study and reminded them that data files must be uploaded to the Google Drive prior to their video call with the researcher.

Video call assessments

Assuming the pre-video call assessments were completed, approximately 15 minutes before the scheduled video call, participants received an email from the researcher with three hyperlinks. The first was un-numbered and was an invitation to a video call via Zoom where participants could click when they were ready to do so. Below this were two links, as with the previous assessments, coupled with instructions not to click these links until the researcher instructs to do so. Once on the video call, the researcher would ask for confirmation of the successful completion of the pre-video call assessments. If this was not done, participants were unable to proceed with this aspect of the study, until this was amended. If participants confirmed they had successfully completed the initial assessments, the researcher continued to explain that the reason for the video call was that there were some tests that required verbal administration and response. There was further explanation of the pre-video call assessments and that the cognitive battery they were about to complete would be similar to the E-Prime computerised tasks that concluded the former.

Both short-term aspects of the RPA-PMT were explained to participants before continuing with other tests in this session. Once participants understood what they were to remember for the RPA-PMT, the VPA-I followed. The sub-test consisted of eight word-pairs that once read out by the researcher, the researcher would then read out the first word in the word-pair with the participant having to respond with the word that completes that word-pair. Participants had five seconds in which to respond with an answer before the researcher moved onto the next item. This process was done four times with participants accuracy scores recorded.

Next, the researcher guided participants to the first set of computerised tasks in session two. Participants were provided with a hyperlink that directed them to a google drive with the E-Prime GO documents. The four tests within this drive were numbered from 1-4 and consisted of Digit-Span forward/backward, Stop-Signal and colour Stroop. The order in which participants completed these were counterbalanced. Participants were instructed to complete the first two tests in numerical order and then to await further instruction from the researcher. For the purposes of this thesis, the order in which participant 001 completed the tests will be described.

The first E-Prime test that participants had to complete was the Digit-Span Forward test, which measured short-term memory followed by a Stop-Signal task which measured inhibitory control. Once participants had completed these tasks and made this aware to the researcher, participants were informed that a five-minute break was about to begin, in which they could do as they pleased. This was the event-based short-term task of prospective memory and once the researcher started the break timer, participants had until 5:00 to ask the researcher what the weather was like where they were. Any response after this was recorded as incorrect.

After the short break, participants long-term memory was assessed using VPA-II. This was similar to VPA-I in that participants were to verbally complete the word-pairs after the researcher had prompted the first half of the word-pair. The difference in this recall task is that the researcher did not read out the whole word-pair list, instead beginning just with one half of the word-pair, assessing whether participants remember the word-pairs from 25-35 minutes prior. This delay period matches the instructions provided in the WMS-III suggests and is the time that had elapsed since then due to the two E-Prime tasks and the short break. Again, accuracy scores were recorded, however, participants had an increased response window of 10 seconds as opposed to the 5 seconds offered in VPA-I. Following this, a recognition task was also administered. This included 24 word-pairs whereby the task was for participants to respond “yes” if it was a word-pair that was asked to be remembered in VPA-I, or “no” if it is a new word-pair. These were split evenly with 12 being a match and 12 being new word-pairs. As there were only eight original word-pairs, half of these were repeated. Accuracy scores were recorded.

Following VPA-II, participants were instructed to return to the google drive where four tasks were located having completed the first two, Digit-Span Forward, and Stop-Signal tasks. Again, participants were instructed to complete the next two tasks and inform the researcher when they had done so. The next task was Digit-Span Backwards, which, like the Corsi Block Test and N-back tasks in the previous session, assessed working memory. The final of the four tasks in the Google drive was a colour Stroop task which, like the Stop-Signal task earlier in the video call, measured inhibitory control. Completing this task would be the final computerised task for one in every four participants with these tasks counterbalanced. Once participants had made the researcher aware that they had completed the E-Prime tasks the researcher would verbally administer the final set of instructions. This would comprise the second half of the RPA-PMT which involved long-term measures of prospective memory.

This was the end of this second session. The researcher offered to remain on the video call to aid participants in locating their E-Prime data and loading it to the correct Google drive, although they had done this previously. Participants were thanked for their time and for taking part in the study and the video call was terminated by the researcher. Participants that took part for a second time, six months after initial participation, took part in the same procedure for a second time, with tasks counterbalanced from the order they completed them the first time.

2.1.6 Data Analysis

Data from Qualtrics was transferred to a Microsoft Excel document before being analysed in SPSS 25.

2.1.7 Ethics

The present study adhered to British Psychological Society (BPS) guidelines, with data collection only permitted following ethical approval from the Departmental Research Ethics Committee (DREC) at Edge Hill University. All participants were fully informed of the aims of the study prior to taking part, through the participation information sheet that was emailed to them and was again presented on the opening screen of the survey in the pre-video call assessments. The participation information sheet informed participants of their rights as a participant before, during and after the study, including their right to withdraw at any point during the study without penalty. They were also made aware that they had until 23:59, fourteen days after taking part in the study to request the removal of their data from the data analysis without having to give reason for doing so. Following the screen displaying the participant information sheet, all participants provided full informed consent via the tick box options provided to various statements. All participants were required to be over the age of 18 at the time of participating in the study and able to provide full informed consent. All participants were emailed an electronic copy of a debrief and referral sheet with some explanation of their results upon request seven days after participating in the video call assessments of the study. Those that did not request this were emailed their debrief sheet on the next working day. Not only would this provide participants with a basic indication of how they performed on the cognitive tasks, but also reiterated the aims of the study and providing information of the issues that were raised.

2.2 Study 6

2.2.1 Participants

The study population consisted of nine post-concussed athletes. Participants were recruited via advertisements on social media platforms such as Twitter and LinkedIn as well as word of mouth. All participants took part in semi-structured interviews designed to investigate their attitudes and knowledge towards concussion in amateur rugby.

2.2.2 Design

Semi-structured interviews (Appendix S) were administered with the aims of identifying potential poor attitudes and general misconceptions regarding concussion in sport. For this reason, participants that had sustained SRC were sought to give their views on concussion and any protocols that they had to follow, whether they did or not and whether having concussion has changed their views.

2.2.3 Measures

Virtual conferencing platform - Zoom

Zoom is a free secure online video conferencing service, which was utilised for the interviews in this study. Interviews were recorded using the researcher's laptop. Upon completion, the researcher would terminate the video call and when doing so an option to save audio and video from the meeting. Due to anonymity obligations specified in the ethical approval obtained from the university, only audio was saved for transcription purposes, maintaining participant anonymity.

2.2.4 Procedure

Given the COVID-19 pandemic, all interviews were administered, and recorded on Zoom. Shortly before the interview began, participants were sent an email with two links, one to an electronic participant information sheet (appendix D) and consent form (appendix B) which was to be completed before clicking the second link which took them to the video call with the researcher. Consent forms were checked to make sure they were completed before the interview commenced. The interview began with a short introduction before “warm-up” questions were asked to help the participant feel at ease with sharing information with the researcher. These included generic questions regarding general sporting participation and their competitive nature before asking them of their experiences with concussion.

The semi-structured nature of the interviews meant that they could be guided by interviewer or interviewee depending on what the interviewee responses were. There were five main areas that the researchers were interested in; education of concussion, increasing knowledge of concussion, current knowledge of the dangers of concussion, continuing participation with suspected concussion, and recovery period attitudes with the researchers interested in both the participants’ views on these criteria as well as their teammates’ managers. This approach was adopted to prevent participants’ providing the researcher with what they felt the researcher wanted to hear, and developing an understanding of the environment that they have played in.

Interviews lasted approximately one hour, and participants were emailed a debrief form (appendix E) following the video call.

2.2.5 Data Analysis

Thematic analysis (TA) is a widely used technique in qualitative sport and exercise research (Braun & Clarke 2006; Hallett & Lamont, 2015) and therefore was adopted in the present study. Given that Braun and Clarke have been consistently concerned with the usage of their approach since their initial paper was published, we followed the six-phase process that the authors proposed (Braun & Clarke, 2012). Although these steps are presented in a logical sequential order, this is not a linear process and therefore we moved back and forth through these steps during analysis. A worked example is provided below:

2.2.5.1 Phase one: Familiarisation with the data

At this phase, I began to familiarise myself with the data by listening to each interview recording before transcribing them. This was initially done taking no notes, so to only listen and remind myself of the context of the discussions that took place. I then manually transcribed each interview, again facilitating my familiarisation of the data. This felt like a worthwhile task, and I felt closer to the data, and the stories in which each participant was recalling. Following transcription of interviews, I read back each transcript numerous times. During this process, I took brief notes of my thoughts at the time of what I considered to be interesting aspects of the data. Examples of these are presented in Box 1.

"All participants discuss continuing playing with a suspected concussion however none seem concerned that they have."

"Stereotypical attitudes in rugby regarding not appearing weak."

"Participants refer to concussion knowledge as a learned experience. All have different knowledge based on their accounts and experiences, rather than information that has been presented to them."

"Player numbers appear to be an issue for substitutions."

Box 1 Example of preliminary notes taken during phase one.

2.2.5.2 Phase two: Generating initial codes

The preliminary iteration of coding was conducted using the *nodes* feature in NVivo12. This feature allowed me to produce and save codes, alongside reading the transcripts. Another useful feature of this software is that the number of times these codes are used are also displayed in the current transcript and across all transcripts uploaded to the specific document. Codes would be noted in the side margin as well as highlighting the text that I had coded to each respective code. A brief example of the preliminary coding process of one participant's interview transcript is presented in Box 2.

I've seen stuff in the news of people from rugby back in the day like a lawsuit over their head injuries or something. [C1] I think at this uni, most of them realise if you have too many concussions, it's not going to be good, so they are quite careful. I know they do, I think they do know that if you have a lot of concussions there will be like consequences in the future. [C2] I think the only issue we've had was physical like getting sleepy and that kind of stuff. [C3] I always play rugby in a scrum cap as I don't want to get a concussion [C4] and it's more like a confidence thing as well. I had a lot of times where I've been hit with elbows or knees in the head but because I had a scrum cap on it barely hurt whereas if I didn't have one it would probably hurt quite a lot. [C5] I always had like the mentality if you back out you're going to get injured, so you just go all out for it. [C6]

[C1] Awareness of issues.

[C2] Basic knowledge of concussion consequences.

[C3] Basic knowledge of concussion symptoms.

[C4] Poor concussion knowledge. Scrum caps do not protect from concussion.

[C5] Misplaced confidence. Carelessness towards concussion risk.

[C6] Carelessness

Box 2 Extract of preliminary coding

2.2.5.3 Phase three: Generating themes

I did not begin this phase until all information I deemed relevant was coded as per phase two. Where codes are the interpretation of individual data items from the transcripts, themes are considered meaningfulness across the dataset (Byrne, 2022). I reviewed the codes in NVivo12, analysing how some of them may be more relevant than others and how some may be combined if they share meaning and usefulness. When analysing the data, I used the codes to develop initial candidate themes and a thematic candidate map of the initial candidate themes is displayed in figure 2. The themes *poor attitudes* and *poor knowledge* were clearly definable with codes that were clearly related to those two aspects of meaning. The theme of *continued participation* seemed to be a product of the first two candidate themes. That is, continued participation would not occur but for poor attitudes towards and poor knowledge of concussion from the player.

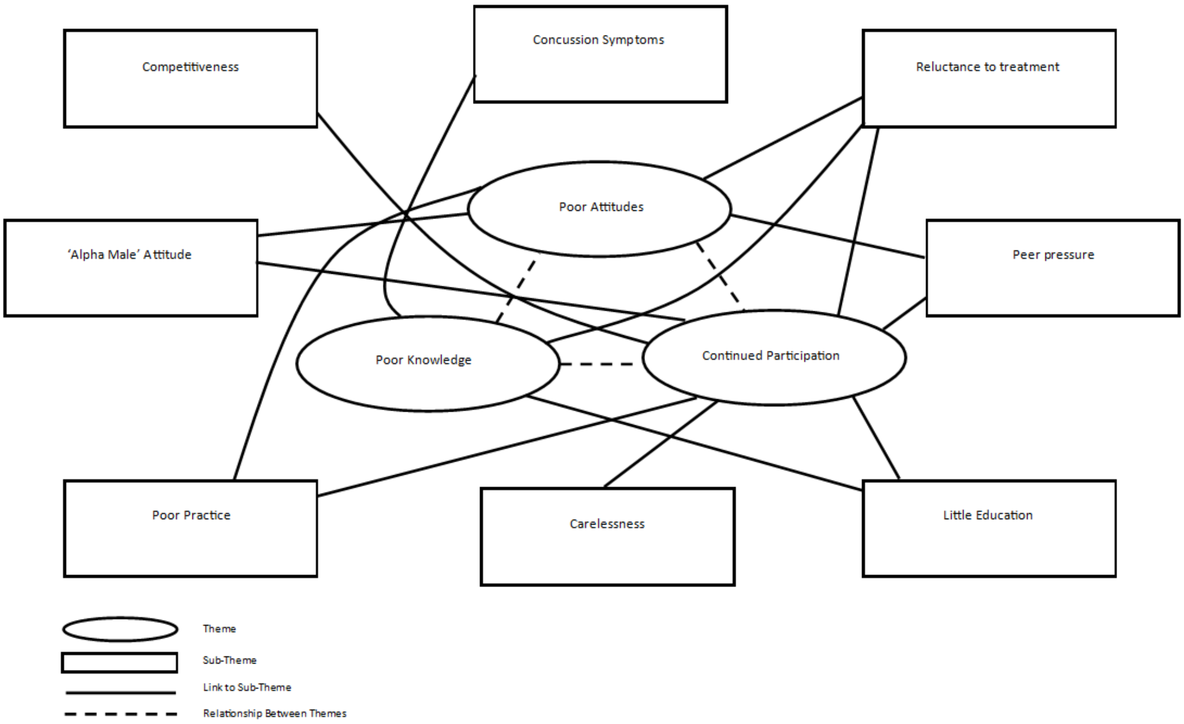

Figure 2. Initial thematic map indicating three candidate themes

2.2.5.4 Phase four: Reviewing potential themes

During this stage of analysis, Braun and Clarke suggest that there ought to be two levels of review. At level one, the researchers should analyse the relationships among the codes that inform each candidate theme. If they form a coherent pattern and a logical argument, it makes sense that they contribute to the overall narrative. In level two, themes are assessed as to how well they represent the data in relation to the research questions.

During level one review, it became evident that there were some issues regarding whether the candidate themes were indeed themes. When analysing the sub-theme *reluctance to treatment,* in relation to the three candidate themes, it appeared that in my view it was related to all three. This is that a reluctance to treatment could be due to *poor attitudes* and *poor knowledge* and can lead to *continued participation*. However, using Braun and Clarke's (2012) series of key questions recommended for this stage of analysis, I began to ask how much these themes tell us. “Are there enough (meaningful) data to support this theme (is the theme thin or thick)?” It could be argued that they are too thin, and that they do not actually explain the dataset in its fullest.

Due to this, during level two review, I was concerned that the three candidate themes *poor attitudes, poor knowledge,* and *continued participation* may violate more of these key questions that Braun and Clarke (2012) pose when reviewing potential themes. For example, Braun and Clarke (2012) pose the question “If it is a theme, what is the quality of this theme (does it tell me something useful about the dataset and my research question)?” At this stage, it could be argued that *poor attitudes, poor knowledge,* and *continued participation* merely describe what is going on in the dataset but fails to illustrate why it is happening. It is my interpretation that poor attitudes and poor knowledge perhaps lead to continued participation, but what are driving these poor attitudes and knowledge? Therefore in this stage, when investigating the three candidate themes in relation to one another, this formed the basis of a new interpretation. That is, that there is a *poor duty of care*. Participants continuously referred to examples where coaches, teammates, officials, and doctors had all failed in their duty of care by misidentifying or ignoring concussion symptoms and allowing them to continue when concussion was suspected. This also led to another theme being developed *incompetence*. There were numerous examples where participants referred to non-players not being correctly qualified to understand and identify concussion and therefore this can explain the poor duty of care that is leading to poor attitudes, poor knowledge, and continued participation in amateur rugby. The outcome of this dual-level review led to the finalised thematic framework that can be seen in figure 3.

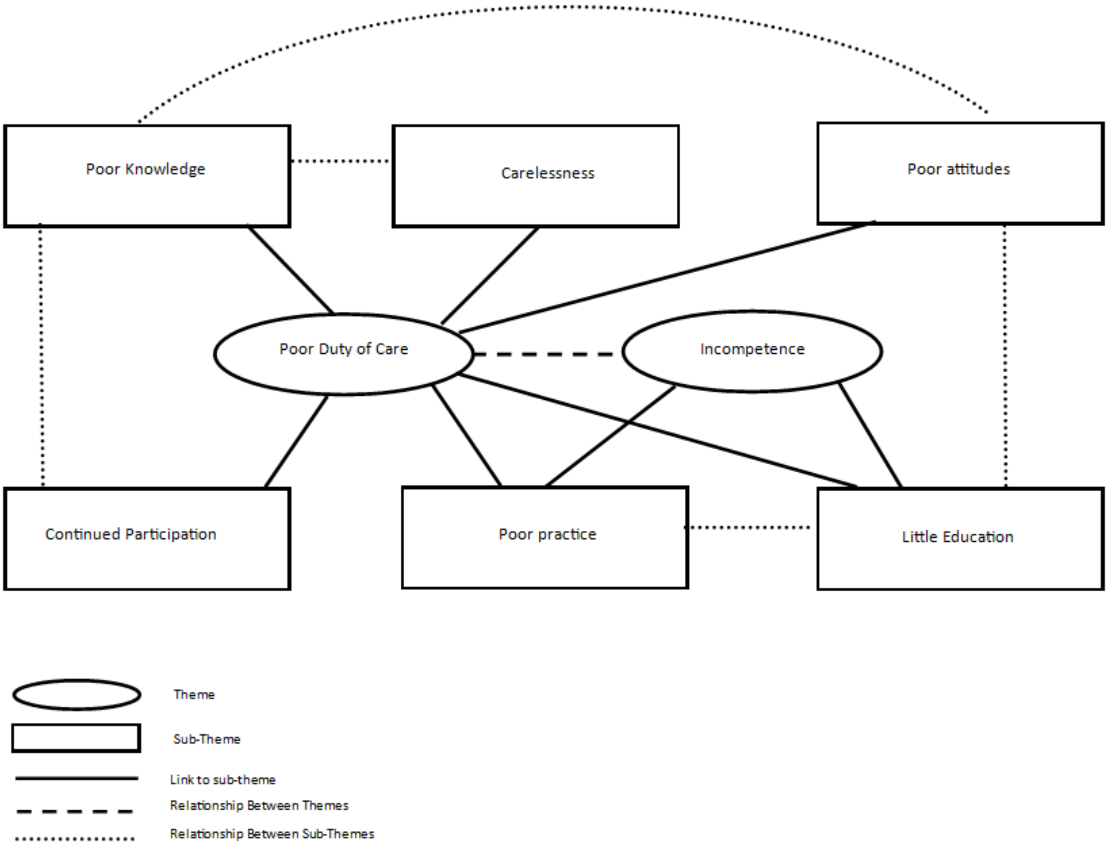

Figure 3. Finalised thematic map demonstrating two themes

2.2.5.5 Phase five: Defining and naming themes

Patton's (1990) dual criteria suggests that each theme should provide a logical account of the data that cannot be explained by other themes. However, all themes should come together to present a narrative that explains the content of the dataset and answers the research question. It is here that the final revision of the naming of the themes is formed and extracts from participant accounts are selected for the final report. It was deemed that *poor duty of care* was a viable theme that helps to explain the reasons as to why some amateur rugby players possess poor attitudes towards concussion and can lead to continued participation with suspected concussion. Additionally, the theme *incompetence* was decided as a fitting theme to help explain the process that underpins this shortfall of care for amateur athletes, whether that is from coaches, match officials or club doctors.

2.2.5.6 Phase six: Producing the report

As with the previous five phases, this phase was not the finale of a linear process, and instead this write-up of themes was conducted throughout the whole process of analysis, consistently written and re-written. Byrne (2022) advises that themes should connect in a logical and meaningful manner to create the narrative, and where possible should build upon previously reported themes. From this, I reported *poor duty of care* first as this theme helps explain the main issues surrounding concussion in amateur rugby. These include common unsafe attitudes towards concussion from players, which may be a product of the poor knowledge and attitudes of their coaches. A poor duty of care contributes to this as we see numerous examples of continued participation where coaches, match officials and club doctors have all failed in protecting the potentially concussed player. The second theme *incompetence* builds on the first theme by explaining why these examples of poor duty of care may occur. It seems that coaches, match officials and club doctors are not competent in detecting concussion symptoms, and therefore this makes it very difficult to ensure their players receive appropriate care.

2.2.6 Ethics

British Psychological Society (BPS) ethical guidelines were adhered to with data collection commencing after ethical approval was obtained from Edge Hill University's Departmental Research Ethics Committee (DREC). A participant information sheet informed participants of the nature of the study and their rights as a participant including details on the withdrawal of data if they wished to do so. All participants were 18 years or older at the time of completing the study. After the interview, a debrief form was emailed to them reiterating the aims of the study and reminding participants how to withdraw their data if they wished to do so.

2.3 Study 7

2.3.1 Participants

The study consisted of 188 male (*n* = 57, *M* = 25.63, *SD* = 5.61) and female (*n* = 130, *M* = 22.08. *SD* = 5.53) respondents that were utilised to compare standardised physical pain questionnaires and validate the proposed physical pain questionnaire. In total, participants completed three pain questionnaires as well as a survey collecting demographic variables so comparisons between different groups could be made.

2.3.2 Measures

General Information Questionnaire (GIQ)

The General Information Questionnaire (GIQ) was designed by the researchers to record demographic variables. This tool included two items: biological sex and age. Multiple-choice options were provided for biological sex (Male/Female, *note: gender was not investigated*) and a free-text response was utilised for age.

Localised Pain Scale (LPS; Appendix T)

This scale was a new experimental scale whose results would be compared with the Numeric Ratings Scale-11 (NRS-11; Downie et al., 1978) and Visual Analogue Scale (VAS). This questionnaire consisted of the same set of questions asked twice, once for the pain experienced *right now* (Y-1) and a second time for pain experienced *in the past week* (Y-2). The scale consists of 8 items on a 7-point Likert scale (0-6) with zero indicating ‘no pain’ one to two indicating ‘mild pain’ three to four indicating ‘moderate pain’ and five to six indicating ‘severe pain’. The sum of scores is therefore 0-6 on each item, with higher scores representing worse physical pain experienced.

Numeric Ratings Scale-11 (NRS-11; Downie et al., 1978)

This scale is a simple 11-point Likert scale whereby respondents provide a score between zero and ten on the level of physical pain they have experienced in the past week. Zero indicates 'no pain', one to three indicates 'mild pain', four to six indicates 'moderate pain' and seven to ten indicates 'severe pain'. Higher scores represent worse physical pain.

Visual Analogue Scale (VAS)

Similar to NRS-11, this scale utilises a slider where participants provide an answer to where their physical pain in the past week falls. The furthest to the left is 'no pain at all' and the furthest to the right is 'the worst pain imaginable'.

2.3.3 Procedure

Upon agreement to participate, the participants were given a URL link to an online survey page using Qualtrics (Qualtrics, Provo, UT). Following a participant information sheet (appendix F) and an electronic consent form (appendix B) was the General Information Questionnaire (GIQ) and the pain questionnaires (LPS; NRS-11; VAS). A study debrief form (appendix G) was presented at the end.

2.3.4 Data Analysis

Scores of internal consistency, correlations and factor analysis were conducted using IBM SPSS Statistics (Version 25).

2.3.5 Ethics

All British Psychological Society (BPS) guidelines were adhered to alongside ethical approval from the University's Science Research Ethics Committee. Participants were informed of the aims of the study prior to taking part, through the participant information sheet presented on the opening screen of the survey. Following this, all participants provided full informed consent via the tick box options provided to various statements, with the survey designed to disallow participants that failed the consent requirements. An electronic copy of a debrief and referral sheet was presented at the end of the study, reiterating the aims of the study, and providing participants with information of the issues that were raised.

Chapter 3: Study 1 – Investigating sport-related concussion and physical pain simultaneously to understand their impact on mental health and quality of life

3.1 Abstract

Research on sport-related concussion (SRC) often ignores the role that physical pain may have on mental health and quality of life. This study is therefore investigating the impact of SRC and physical pain on depression, anxiety, and quality of life, in isolation and combined. Depression was assessed using the Center for Epidemiological Studies Depression Scale, anxiety was recorded using the State-Trait Anxiety Inventory and quality of life was measured using the Health-Related Quality of Life Short Form-12. Analysis of 80 participants (Concussed, n=57) revealed that SRC was responsible for elevated depression and trait anxiety and reduced quality of life. However, when physical pain was added to the model, SRC was only responsible for increased depression and reduced quality of life and physical pain was associated with all measures of mental health and quality of life. Therefore, the role of physical pain may be overlooked within SRC research and vice versa and the two should be investigated simultaneously in future studies.

Keywords: Depression, State-Trait Anxiety, Quality of Life, Sport-Related Concussion, Physical Pain

The introduction section below is a summary of past research that was presented in Chapter 1.

3.2 Introduction

Collins et al. (2018) states there are an estimated 1.6-3.8 million cases of sport-related concussion (SRC) reported annually in the USA. This figure is much higher than the 300,000 cases reported in previous decades (Sosin et al., 1996). Though this may be due to improved diagnoses (Rosenthal et al., 2014), it does indicate that athletes are at high risk of sustaining SRC and therefore also at risk of experiencing the negative consequences associated with SRC. Poor mental health (Gouttebarge & Kerkhoffs, 2021) and reduced quality of life (Gard et al., 2020) are among the most reported negative outcomes of SRC, which highlights the importance of researching this area. Although SRC and physical pain often co-occur (Mollayeva et al., 2017; Provance et al., 2020), the two are rarely investigated together. This shortcoming is surprising given that physical pain has the same negative impact on mental health (Humo et al., 2019; Nekovarova et al., 2014; Walker & Marchant, 2020) and quality of life (McVige et al., 2018; Voormolen et al., 2019). Therefore, it is necessary to examine SRC and physical pain simultaneously to determine which is more responsible for poor mental health and reduced quality of life.

Concussion and depression share symptoms such as sleep disturbances, irritability, concentration, and memory impairments, which may explain their comorbidity. Generally, those that have sustained concussion report higher depressive symptoms than those that have not. Prevalence rates can range between 15.6-21% (Wolanin et al., 2016; Yang et al., 2007) which visibly exceeds the 3.8% in the general population (WHO, 2023). Considering this, Pryor et al. (2016) attempted to determine if concussion increased the incidence of depression in semi-professional and professional North American football players using the Center for

Epidemiological Studies Depression Scale (CESD; Radloff, 1977) to measure depressive symptoms. Analyses found that CESD scores of ≥16, the recommended cut-off symbolic of experiencing some form of depression (Husaini et al., 1980), were associated with significantly more concussions. Further analysis revealed significantly higher CESD scores in players who had sustained three or more concussions compared to those that have sustained two or less. Moreover, depression and anxiety are highly comorbid, with strong associations reported in post-concussed (Yang et al., 2015) and non-concussed samples (Walker & Marchant, 2020). Therefore, when investigating mental health, it is plausible to research both depression and anxiety.

The effects of depression and anxiety are likely to negatively impact quality of life (Angermeyer et al., 2002) which has led to researchers examining the influence that SRC has on this outcome. Voormolen et al. (2019) recorded quality of life using the Health-Related Quality of Life Short Form-36 (SF-36; Ware et al., 1994) which has demonstrated good internal consistency in mTBI populations (Diaz et al., 2012; Guilfoyle et al., 2010). Analyses revealed that participants with PCS had significantly lower scores on SF-36, indicating a link between concussion and reduced quality of life. Similar results were reported by Ponsford et al. (2019), who found that quality of life scores, recorded using SF-12 (Ware et al., 1996), were significantly correlated with post-concussion symptoms. Therefore, not only is there an association between concussion and lower quality of life but Ponsford et al.'s (2019) findings validate the use of the shorter SF-12 when assessing post-concussed samples.

SRC and physical pain often co-exist (Mollayeva et al., 2017; Provance et al., 2020), however, the two are often investigated exclusively. This gap is surprising when physical pain has been found to share the same negative consequences associated with SRC on mental health (Humo et al., 2019; Nekovarova et al., 2014; Walker & Marchant, 2020) and quality of life (Gard et al., 2020; Niv & Kreitler, 2001). When assessing physical pain without concussion, Walker and Marchant (2020) found that those displaying depressive symptoms reported significantly higher scores of self-reported physical pain than those without depressive symptoms (using the established CESD cut-off $\geq$16; Husaini et al., 1980). However, as concussion history was not accounted for, we cannot be sure that the physical pain scores that were attributed to influencing depressive symptoms did so. Alternately, the same could be said vice versa in concussion research such as Yang et al.'s (2007) study that did not account for physical pain. Therefore, SRC and physical pain should be investigated together to develop a greater understanding of the mechanisms that result in poorer mental health and reduced quality of life. This study aimed to do this by investigating how SRC and physical pain, in isolation and combined, contribute to depression, anxiety, and quality of life.

3.3 Method

Participants

Participants' demographic information is depicted in Table 1. Participants were recruited via the online departmental participant recruitment system, advertisements on social media platforms LinkedIn and Twitter as well as word of mouth. SRC history was self-reported. A minimum of 28 days must have passed following their concussion before participants of this group were eligible to take part in the study, to avoid exacerbating post-concussion symptoms due to surveys displayed on a computer screen. SRC occurred 1-48 months prior to taking part in this study (M = 19.00, SD = 14.38).

Sample size calculations

Sample size was calculated using G*Power 3.1.9.7. A priori calculations indicated that 82 participants were required (across the two groups) to achieve adequate power (β =0.9) to detect an effect size of $f^2 = 0.2$ at $\alpha = 0.05$. Therefore, the sample in this study falls just short to achieve this level of power. Post-hoc calculations were conducted to compute the power achieved with the sample obtained. It was found that the sample of 80 participants achieved adequate power (β =0.89) detecting an effect size of f = 0.2 at α = 0.05, and therefore the sample was not underpowered.

Table 1. Participant characteristics

			Age	
		N	*M*	*SD*
Total		80	23.49	5.43
Sex	Male	57	24.44	5.84
	Female	23	21.13	3.28
Student Status	Student	26	21.19	3.83
	Non-student	54	24.59	5.76
SRC History	Yes	57	23.75	5.61
	No	23	22.83	5.02

Measures

Refer to Chapter 2 for below measures:

- General Information Questionnaire (GIQ)
- Numeric Rating Scale (NRS-11; Downie et al., 1978)
- Center for Epidemiological Studies Depression Scale (CESD; Radloff, 1977)
- State-Trait Anxiety Inventory (STAI; Speilberger et al., 1970)
- Health Related Quality of Life: SF-12 (SF-12; Ware et al., 1996)

Reliability Statistics

Reliability statistics were calculated by conducting a Cronbach's Alpha. Analyses revealed internal consistency scores of α = .93 for CESD, α = .95 for STAI (state) α = .95 for STAI (trait) and which are considered excellent scores (Sharma, 2016). SF-12 produced a score α = .85 which Sharma (2016) describes as a good score.

Data Analysis

Data analysis was conducted using IBM SPSS Statistics (Version 25). Pearson correlations were run to identify any relationships between concussion history, physical pain, depression, state/train anxiety and quality of life. A one-way MANOVA was used to examine the effect of concussion on depressive symptoms, state/trait anxiety symptoms and quality of life whereas a MANCOVA was utilised to examine these factors when controlling for physical pain.

Refer to Chapter 2 for information regarding procedure and ethics.

3.4 Results

Assumptions

MANCOVA assumes that the independent variables are categorical, and the dependent variables are continuous (Finch, 2005). In this study, the independent variable was SRC history (yes/no) and therefore this is a categorical variable, whereas the dependent variables were depression, state-trait anxiety and quality of life scores which were recorded on a scale, and therefore were continuous. Covariates can be either continuous, ordinal, or dichotomous, so the continuous recording of physical pain on a Likert scale was acceptable here and the level and measurement of variables assumption was adhered to in this study. Correlational analysis was used to measure assumptions of multicollinearity and relationships between covariate and dependent variables. Here we identified that there was an absence of multicollinearity as correlations were all below $r = .90$, guidelines that Tabachnick & Fidell (2012) suggest which satisfies these two assumptions. Normality was tested using Shapiro-Wilk analysis between SRC groups. It was revealed that only depression scores in the non-SRC group were normally distributed ($p > .05$) whereas scores for all other dependent variables in both groups were not normally distributed (all $p < .05$). Therefore, the assumption of normality was violated for most dependent variables in this sample. However, Everitt (1979) reports that this violation has a limited impact on type I error rate for MANOVA. Additionally, Box's M Test of Equality of Covariance Matrices was significant

(p = .001) suggesting a violation of homogeneity of covariance matrices assumption. Allen & Bennett (2008) claim that if both groups contain over 30 participants, then MANOVA is robust against this violation. As the non-SRC group falls below this value (n = 23) our findings should be inferred with caution.

Correlations

The results from correlation analysis are presented in Table 2.

Table 2. Correlations between independent variables and covariate

	Depression	State Anxiety	Trait Anxiety	Quality of Life	Physical Pain
Depression	1	-	-	-	-
State Anxiety	.824*	1	-	-	-
Trait Anxiety	.843*	.819*	1	-	-
Quality of Life	-.870*	-.755*	-.846*	1	-
Physical Pain	.425*	.348*	.395*	-.512*	1

*- $p < .01$

MANOVA

The MANOVA revealed a significant effect of SRC on depression, $F(1, 78) = 6.77$, $p = .011$, $\eta_p^2 = .080$, trait anxiety, $F(1, 78) = 4.26$, $p = .042$, $\eta_p^2 = .052$, and quality of life $F(1, 78) = 9.02$, $p = .004$, $\eta_p^2 = .104$. However, there was no significant effect on state anxiety ($p = .081$).

MANCOVA

The MANCOVA revealed a significant effect of SRC on depression, $F(1, 77) = 5.51$, $p = .021$, $\eta_p^2 = .067$ and on quality of life, $F(1, 77) = 7.98$, $p = .006$, $\eta_p^2 = .094$. However, there was now no effect on state anxiety ($p = .143$) and trait anxiety ($p = .080$). There was a significant effect of physical pain on depression $F(1, 77) = 15.64$, $p < .001$, $\eta_p^2 = .169$, state anxiety $F(1, 77) = 9.66$, $p = .003$, $\eta_p^2 = .111$, trait anxiety, $F(1, 77) = 13.02$, $p = .001$, $\eta_p^2 = .145$ and quality of life, $F(1, 77) = 26.17$, $p < .001$, $\eta_p^2 = .254$. Descriptive statistics are displayed in Table 3.

Table 3. Descriptive statistics depicting depressive symptoms and quality of life scores by SRC history

	SRC			Non-SRC		
	N	*M*	*SD*	*N*	*M*	*SD*
Depression	57	17.72	12.28	23	10.70	6.28
State Anxiety	57	38.37	13.14	23	32.87	11.16
Trait Anxiety	57	43.37	13.08	23	36.82	12.18
Quality of Life	57	23.88	6.81	23	28.61	5.11

Post-Hoc Tests

Following this, the assumption of homogeneity of regression slopes was tested as this test is vital when using MANCOVA analyses. The interaction term between SRC history and physical pain did not have any effect on depression, state anxiety, trait anxiety and quality of life scores (all $p > .05$). Therefore, the assumption of homogeneity of regression slopes has been adhered to and we can accept what has been found in the main analysis.

3.5 Discussion

The present study aimed to investigate how SRC and pain, in isolation and combined, contribute to depression anxiety and quality of life in athletes. Analyses revealed that SRC was associated with elevated depression and trait anxiety and a reduction in quality of life which supports previous findings (Pryor et al., 2016; Yang et al., 2015). SRC history has no influence on state-anxiety. However, adding physical pain as a covariate, SRC only negatively impacted depression and quality of life, whereas both state and trait anxiety were now not affected. Moreover, physical pain was found to be associated with all four dependent variables; depression., state/trait anxiety and quality of life, which mirrors previous findings (Nekovarova et al., 2014; Voormolen et al., 2019; Walker & Marchant, 2020; Walker & McKay, 2022). Therefore, the conclusions that can be drawn alter when adding physical pain to the model, which was the main aim of this study.

There are numerous studies that suggest SRC is associated with poor mental health (Gouttebarge & Kerkhoffs, 2021; Wolanin et al., 2015; Kontos et al., 2016) and reduced quality of life (Gard et al., 2020; Kuehl et al., 2010), and there is also evidence that physical pain has the same negative influence (Humo et al., 2019; McVige et al., 2018; Nekovarova et al., 2014; Voormolen et al., 2019; Walker & Marchant, 2020). Although the two regularly coincide (Mollayeva et al., 2017; Provance et al., 2020), they are rarely investigated simultaneously. Not accounting for one of these factors is detrimental and can lead to misled conclusions. This study provides evidence that this may be the case in current SRC and physical pain literature. Without accounting for the role of physical pain in this study, we would conclude that SRC negatively influences trait anxiety. However, by adding physical pain into the model we now know this is not the case, and that physical pain is more responsible for the elevated trait anxiety symptoms rather than SRC history. Researchers should consider this when conducting research into SRC and physical pain, with our recommendation that the two should be assessed together.

3.6 Limitations

Although the sample size appears relatively small, sample size calculations revealed excellent statistical power, and therefore the risk of type II error was low. There is, however, some level of self-selection bias due to the voluntary nature of recruitment. The study was advertised as investigating SRC and the potential negative consequences of sustaining them. Therefore, it may be that athletes who have experienced different mental health symptoms may be over-represented in the sample, resulting in overestimation of prevalence. This is highlighted by the number of athletes that had sustained SRC (n = 57) compared to those that had not (n = 23) and therefore this should be considered when inferring the results.

3.7 Practical Implications

Beyond recommending that researchers assess SRC history and physical pain simultaneously, it is important coaches and managers, particularly for contact sports whereby concussion is prevalent (Prien et al., 2018), are aware of these consequences post-concussion. By increasing this knowledge base, better support can be offered to athletes, post-concussion, and when experiencing physical pain. This could be increasing social support for those that that have had concussion, and/or are experiencing physical pain or referring them to other types of mental health support such as counselling.

Though there are difficulties in identifying concussion in athletes, and therefore offering the support that may be required to them, it may be harder still to identify those in physical pain. It is likely that athletes will conceal this information due to being perceived as weak (Liston et al., 2018; Wilson et al., 2021) or in fear of losing their position to a teammate (Smith & Milliner, 1994). This makes it trickier to support athletes in pain. One strategy to overcome this would be to present pain questionnaires to athletes anonymously. A mean level of pain could then be produced, and coaches could then tailor training sessions to the whole group if the mean increases from baseline, using their own intuition. This coupled with encouraging athletes that are in pain to utilise different talking strategies with coaches and/or counselling services is likely to improve mental health and quality of life. It should however be noted that anonymity may not be possible for individual sports, but the same technique of completing questionnaires to identify pain levels should be encouraged.

3.8 Conclusions and Future Directions

The present study further highlights the negative consequences of SRC and physical pain on mental health and quality of life. However, most importantly, this study highlights the importance of assessing the two together. There should be an increased focus on the physical pain experienced post-concussion as it may be that this factor is more relevant when assessing mental health and quality of life than the concussive event itself. Likewise, those that are experiencing physical pain regardless of SRC ought to be monitored closely to support these individuals. This would allow us to better care for those that have sustained

SRC, are experiencing physical pain, or both, with coaches and managers encouraged to improve social support for those that have had concussion as well as utilising pain questionnaires to identify those in need of this support.

Given what was found in this chapter, it seems that physical pain is an important factor to consider when examining mental health and quality of life in post-concussed athletes. With that in mind, the next chapter attempts to further investigate this association between pain and poor mental health and reduced quality of life. Rather than using continuous data that the NRS-11 provides, Downie et al. (1978) also provides descriptors of these data, therefore turning them into categorical data; no pain, mild pain, moderate pain, severe pain. The next chapter analyses data in a greater sample size to investigate in depth the influence that pain has on mental health and quality of life and to try and dissociate any impact of SRC history.

Chapter 4: Study 2 – Exploring the impact of physical pain and concussion history on mental health and quality of life

4.1 Abstract

Although there is a high likelihood of physical pain existing following concussion, these factors have rarely been investigated simultaneously. The present study aimed to address this issue by assessing the effect that both concussion and pain have on depression, state-trait anxiety, and quality of life of the victims. Depressive symptoms were assessed using the Center for Epidemiological Studies Depression Scale, state-trait anxiety symptoms were recorded using the State-Trait Anxiety Inventory and quality of life was measured using Health-Related Quality of Life Short Form-12. Data analysis of 187 participants (Concussed 79, Non-concussed 108) revealed that increasing levels of physical pain resulted in higher depression and anxiety and lower quality of life whereas concussion history had no effect on these outcomes. Therefore, it appears that the physical pain following concussion, rather than concussion itself, may be more responsible for mental health decline and reduced quality of life. In future, concussion and physical pain should be assessed simultaneously and separately, to better understand the negative consequences that are currently associated with both factors and in-turn protect those that have sustained concussion and are experiencing physical pain.

Keywords: Physical Pain, Concussion, Depression, Anxiety, Quality of Life

4.2 Introduction

Concussion is recognised as a brain injury that has the potential to cause negative short-term and long-term consequences (Nordström et al., 2020). Among these consequences are poorer mental health (Hind et al., 2021; Turner et al., 2017; Yrondi et al., 2017) and reduced quality of life (Doroszkiewicz et al., 2021; Gard et al., 2020; Voormolen et al., 2019). However, physical pain has also been found to have a very similar negative impact (Ishak et al., 2018; Niv & Kreitler, 2001; Walker & Marchant, 2020; Walker & McKay, 2022). Considering that concussion and physical pain are likely to coincide (Mollayeva et al., 2017; Provance et al., 2020), it is surprising that the two are not exclusively investigated simultaneously. By addressing this gap, we may be able to identify the role that concussion and physical pain have - in isolation and combined, on mental health and quality of life. In turn, this can influence the way in which the affected individuals are treated following a concussion, those that are in physical pain, or both.

When reviewing the literature, it is becoming increasingly evident that those that have sustained concussion, within and outside of sport, display elevated depressive symptoms (Chrisman & Richardson, 2014; Pryor et al., 2016). Given the high comorbidity between depression and anxiety, it is unsurprising that higher levels of anxiety are also often found in those that have sustained concussion (Yang et al., 2015). Alongside this, there is evidence of a reduction in quality of life in those that have sustained concussion (Doroszkiewicz et al., 2021; Gard et al., 2020; Voormolen et al., 2019) which could partially be attributed to the sufferers living persistently with depression and anxiety symptoms. In addition, reduced quality of life tends to exacerbate mental health symptoms. However, as concussion is usually sustained through a sudden physical force impacting the head, neck, or body, physical pain is likely to exist post-concussion (Mollayeva et al., 2017; Provance et al., 2020). As expected, there is evidence that pain can exacerbate depressive symptoms (Ishak et al., 2018;

Walker & Marchant, 2020; Walker & McKay, 2022) and reduce quality of life (Niv & Kreitler, 2001; Voormolen et al., 2019), and therefore this makes it difficult to differentiate between which factor is leading to these negative outcomes.

The brain suffers an energy crisis when concussion occurs (Giza & Hovda, 2014; Hovda, 2014), and this manifests as post-concussion symptoms (e.g., fatigue, dizziness, loss of concentration and memory etc.). Given that there are many studies that suggest sustaining concussion can have a negative impact on mental health (Didehbani et al., 2013; Gouttebarge & Kerkhoffs 2021; Kerr et al., 2014) and quality of life (Russell et al., 2017), it is plausible to suggest that persisting post-concussion symptoms could point towards an enduring energy crisis that in-turn leads to poorer mental health and reduced quality of life.

Although the above argument explains why those that have sustained concussion may be more likely to experience negative changes to their mental health and quality of life, it does not account for the influence of physical pain. It is estimated that approximately 20% of the general public live with chronic pain worldwide (Breivik et al., 2006; Goldberg & McGee, 2011; Gureje, 2008), and therefore, there will be many more that are living with lesser, but still important, levels of physical pain. There are numerous studies that provide evidence of a link between physical pain and poor mental health (Ishak et al., 2018; Walker & Marchant, 2020; Walker & McKay, 2022) and reduced quality of life (Niv & Kreitler, 2001) which could be explained by shared neural pathways between pain and depressed mood (Nekovarova et al., 2014). Therefore, at present it is unclear whether poor mental health is due to an energy crisis through sustained concussion or due to physical pain sharing neural pathways with Major Depression Disorder (MDD).

Therefore, as concussion and physical pain often co-occur (Mollayeva et al., 2017; Provance et al., 2020) and both are related to poorer mental health (Chrisman & Richardson, 2014; Ishak et al., 2018; Pryor et al., 2016; Walker & Marchant, 2020; Yang et al., 2015) and reduced quality of life (Doroszkiewicz et al., 2021; Gard et al., 2020; Voormolen et al., 2019), it is important to better understand the root of these negative outcomes. To our knowledge, there are currently no studies that have investigated these two factors simultaneously, and therefore we attempted to address this gap. The present study aims at identifying whether the concussion per se or physical pain post-concussion is the major factor affecting mental health and quality of life decline. By doing so, we are better placed to support individuals that have sustained concussion, are experiencing physical pain, or both.

4.3 Method

Participants

One-hundred-and-ninety participants completed questionnaires measuring depression and anxiety symptoms as well as quality of life. However, three were identified as outliers and therefore 187 participants were retained in the sample. Participants demographic information is presented in Table 1. Seventy-nine of this sample self-reported having sustained concussion and these participants also completed the Post-Concussion Symptom Scale (PCSS), as well as reporting whether this was sustained in a sporting setting or elsewhere. The number of months since concussion ranged from 1 to 48 months (M = 19.56, SD = 14.51). Just over two-fifths of the sample identified as athletes with 60% of these individuals most recently competing at an amateur level (University – 21.3%, Semi-professional – 8.8%, County – 7.5%, National – 2.5%).

Sample size calculations

Sample size was calculated using G*Power 3.1.9.7. A priori calculations indicated that 160 participants were required (across the two groups) to achieve adequate power (β =0.9) to detect an effect size of $f^2 = 0.1$ at $\alpha = 0.05$. Therefore, our sample of 187 participants achieves the threshold of statistical power set. Post-hoc calculations were conducted to compute the actual statistical power (β =0.94).

Table 1. Participant characteristics

			Age	
		N (%)	*M*	*SD*
Sex	Male	83 (44.4)	23.09	5.33
	Female	104 (55.6)	20.54	3.23
Student Status	Student	54 (28.9)	20.48	3.00
	Non-student	133 (71.1)	22.66	4.98
Athlete status	Athlete*	81 (43.3)	23.49	5.39
	Non-athlete	106 (56.7)	20.92	3.52
Concussion History	Yes	79 (42.2)	23.25	5.16
	No	108 (57.8)	21.14	3.93
Type of concussion	SRC	67 (84.8)	23.64	5.43
	NSRC	12 (15.2)	21.08	2.47

*- Self-identify as an athlete.

Measures

The following measures were used in this study.

- General Information Questionnaire (GIQ)
- Numeric Rating Scale (NRS-11; Downie et al., 1978)
- Post-Concussion Symptom Scale (PCSS; Lovell, 2006)
- Center for Epidemiological Studies Depression Scale (CESD; Radloff, 1977)
- State-Trait Anxiety Inventory (STAI; Speilberger et al., 1970)
- Health Related Quality of Life: SF-12 (SF-12; Ware et al., 1996)

Please refer to Chapter 2 for more details.

Reliability Statistics

Reliability statistics was calculated by conducting a Cronbach's Alpha using SPSS 25. Analysis revealed internal consistency scores of $\alpha = 0.92$ for PCSS, $\alpha = 0.93$ for CESD, $\alpha = 0.95$ STAI (state), $\alpha = 0.95$ STAI (trait) and $\alpha = 0.83$ for SF-12 questionnaires, which are all considered good to excellent (Sharma, 2016).

Data Analysis

Correlational analysis was conducted to check for multicollinearity of data. A two-way MANOVA was run to examine the depressive symptoms, state-trait anxiety symptoms, and quality of life between different levels of physical pain and concussion history.

The procedures remained the same as previously described in Chapter 2.

4.4 Results

Descriptive statistics

Descriptive statistics revealed that 30 (16%) of participants reported no physical pain in the week preceding study participation. This was compared to 94 (50%) that reported mild physical pain and 56 (30%) experiencing moderate pain. As only 7 (4%) of participants reported severe levels of physical pain this group were combined with those that reported moderate levels of pain to create a moderate/severe pain group that consisted of 63 (34%) of the sample. Additionally, retrospective PCSS scores ranged from 9-105 (M = 60.96, SD = 23.92).

Assumptions

There are several assumptions that are important for two-way MANOVA (Finch, 2005). Firstly, independent variables should be categorical and dependent variables continuous. In this study, independent variables were concussion history and pain categorisation, and dependent variables were depressive symptoms, state-trait anxiety symptoms and quality of life scores on a continuous scale and therefore these assumptions are satisfied. Additionally, it is necessary that there is independence of observations which means that there is no overlap in participants between groups. As concussion history and pain categorisation were entered into main effects analysis, the two-way MANOVA separates participants into groups based on their concussion and pain reporting and therefore requirements of this assumption are met. There is also an adequate sample size as a rule of thumb is to have more cases in each group than the number of dependent variables being analysed. As there are six dependent variables, the sample obtained satisfies this assumption and this is corroborated with the power achieved in sample size calculations. Outliers were also checked through boxplot, where three participants scores on the SF-12 were deemed as outliers and were subsequently removed. Shapiro-Wilk analysis identified that the data for each of the questionnaires was non-normal (all $p < 0.001$), and therefore the assumption of normality was violated. However, Everitt (1979) reports that this violation has a limited impact on type I error rate for MANOVA. Linear relationships were found between each dependent variable identified through scatterplot and no multicollinearity was reported as demonstrated through correlation analyses below. However, Box's M Test of Equality of Covariance Matrices was significant ($p = .018$) suggesting a violation of homogeneity of covariance matrices assumption. That said, Allen & Bennett (2008) claim that if both groups contain over 30 participants, then MANOVA is robust against this violation. This was the case for both pain categorisation (no pain $n = 30$, mild pain $n = 94$, moderate/severe pain $n = 63$) and concussion history (concussed $n = 79$ and non-concussed $n = 108$) and therefore we can accept findings from MANOVA in this sample.

Correlations

Table 2. Correlations of dependent variables

	CESD	STAI-State	STAI-Trait	SF-12 Total	SF-12 Physical	SF-12 Mental
CESD	-	-	-	-	-	-
STAI-State	.719*	-	-	-	-	-
STAI-Trait	.777*	.797*	-	-	-	-
SF-12 Total	-.770*	-.698*	-.802*	-	-	-
SF-12 Physical	-.594*	-.484*	-.610*	.860*	-	-
SF-12 Mental	-.760*	-.727*	-.814*	.963*	.681*	-

*- $p < 0.01$

MANOVA

The two-way MANOVA revealed a significant effect of pain categorisation on depressive symptoms $F(2, 181) = 5.42$, $p = .005$, $\eta_p^2 = .057$; state-anxiety symptoms $F(2, 181) = 4.89$, $p = .009$, $\eta_p^2 = .051$; trait-anxiety symptoms $F(2, 181) = 5.65$, $p = .004$, $\eta_p^2 = .059$; total quality of life scores $F(2, 181) = 7.21$, $p = .001$, $\eta_p^2 = .074$; physical quality of life scores $F(2, 181) = 4.81$, $p = .009$, $\eta_p^2 = .050$; and mental quality of life scores $F(2, 181) = 9.00$ $p = .001$, $\eta_p^2 = .090$. There was no significant effect of concussion history on depressive symptoms, ($p = .47$), state-anxiety symptoms, ($p = .18$), trait-anxiety symptoms, ($p = .33$), total quality of life scores, ($p = .97$), physical quality of life scores, ($p = .96$), and mental quality of life scores, ($p = .81$). There was a significant interaction effect between pain categorisation and concussion history on state-anxiety symptoms, $F(2, 181) = 3.77$, $p = .025$, $\eta_p^2 = .040$. However, there was no interaction between pain categorisation and concussion history on depressive symptoms, ($p = .59$), trait-anxiety symptoms, ($p = .19$), total quality of life scores, ($p = .42$), physical quality of life scores, ($p = .77$), and mental quality of life scores, ($p = .34$). Descriptive statistics are displayed in Table 3.

Table 3. Descriptive statistics of depressive symptoms, anxiety symptoms, and quality of life scores by pain categorisation and concussion history

		No Pain			Mild Pain			Moderate/Severe Pain			Concussion History		
		N	*M*	*SD*	*N*	*M*	*SD*	*N*	*M*	*SD*	*N*	*M*	*SD*
Depressive Symptoms	Concussion Group	10	13.50	6.55	38	16.00	9.19	31	23.10	13.92	79	18.46	11.58
	Non-Concussion Group	20	16.95	13.50	56	18.07	11.96	32	21.84	11.15	108	18.98	12.06
	Total Group	30	15.80	11.64	94	17.23	10.92	63	22.46	12.50	187	18.76	11.83
State-Anxiety Symptoms	Concussion Group	10	27.60	6.77	38	38.34	10.44	31	44.51	16.40	79	39.41	13.76
	Non-concussion Group	20	38.90	16.03	56	40.00	11.62	32	40.06	10.84	108	39.82	12.22
	Total Group	30	35.13	14.55	94	39.33	11.14	63	42.25	13.93	187	39.64	12.86
Trait-Anxiety Symptoms	Concussion Group	10	37.60	8.68	38	42.21	10.63	31	50.71	14.21	79	44.96	12.79
	Non-concussion Group	20	43.60	14.65	56	45.39	12.38	32	47.69	12.13	108	45.74	12.71
	Total Group	30	41.60	13.12	94	44.11	11.75	63	49.17	13.09	187	45.41	12.72
Total Quality of Life Symptoms	Concussion Group	10	26.90	5.47	38	24.92	4.64	31	20.90	7.18	79	23.59	6.21
	Non-concussion Group	20	25.20	7.04	56	24.80	5.09	32	22.59	6.42	108	24.22	5.93
	Total Group	30	25.77	6.51	94	24.85	4.89	63	21.76	6.80	187	23.96	6.04
Physical Quality of Life Symptoms	Concussion Group	10	9.10	2.51	38	9.08	1.87	31	7.84	2.44	79	8.59	2.24
	Non-concussion Group	20	8.90	2.25	56	8.98	1.80	32	8.19	2.19	108	8.73	2.02
	Total Group	30	8.97	2.30	94	9.02	1.82	63	8.02	2.30	187	8.67	2.11
Mental Quality of Life Symptoms	Concussion Group	10	11.70	2.75	38	10.26	2.45	31	8.06	3.66	79	9.58	3.25
	Non-concussion Group	20	10.85	3.76	56	10.36	2.75	32	9.19	3.16	108	10.10	3.11
	Total Group	30	11.13	3.43	94	10.32	2.62	63	8.63	3.43	187	9.88	3.17

Post-Hoc Tests

Following this, the assumption of homogeneity of regression slopes was tested as this test is vital when using MANCOVA analyses. The interaction term between concussion history and physical pain did not have any effect on depression, state anxiety, trait anxiety, total quality of life scores, physical quality of life scores, and mental quality of life scores (all $p > .05$).

Therefore, the assumption of homogeneity of regression slopes has been adhered to and we can accept what has been found in the main analysis.

4.5 Discussion

The findings from the present study suggest that physical pain is more responsible than concussion history for poorer mental health and reduced quality of life. Our analysis revealed that with increasing levels of pain comes elevated depressive symptoms, state-trait anxiety symptoms, and lower quality of life. This is in line with previous research that has found physical pain to be related to poorer mental health (Walker & Marchant, 2020; Walker & McKay, 2022) and reduced quality of life (Niv & Kreitler, 2001; Voormolen et al., 2019). However, concussion history itself had no effect on mental health and quality of life, suggesting that physical pain may have a larger influence on these outcomes. This is a novel finding considering that concussion per se has often been reported to exacerbate mental health symptoms (Chrisman & Richardson, 2014; Pryor et al., 2016; Yang et al., 2015) and negatively impact quality of life (Blake et al., 2019; Emanuelson et al., 2003). However, the findings of the current study challenged this notion. It appears that concussion research has often overlooked or mis-attributed the impact that physical pain can have on mental health and quality of life (and vice versa), and this study has addressed this misperception. From our findings, we can conclude that physical pain had a larger impact on mental health, such as depressed mood and anxiety and reduced quality of life as opposed to concussion.

Given the complex relationship between concussion and physical pain on mental health and quality of life, an interaction effect may have been expected. In this study, an interaction effect was only associated with state-anxiety scores, perhaps reflecting participant concerns for the outcomes of concussion and physical pain, particularly if they were an athlete. This is corroborated by Smith and Milliner (1994) that found that fear of losing position to a teammate negatively impacts on mental health. This fear may be likely if someone has recently sustained concussion and is experiencing high levels of physical pain. However, it is unclear why there are no other interaction effects for the other dependent variables, and due to this finding, we provide stronger evidence that pain is more responsible for poor mental health and reduced quality of life than concussion history.

4.6 Limitations

The present study was not without its limitations. Firstly, there may be an element of self-selection bias, due to the method of data collection. The study was advertised as aiding research looking at the impact that concussion and physical pain have on mental health and quality of life. Therefore, it could be that those that have sustained concussion and/or are experiencing physical pain that have noticed a decline in their mental health and a reduction in their quality of life may be overrepresented in this sample. That said, as concussion has been found to have no impact on these outcomes, it may also be that potential participants have seen this advert and ignored it, out of fear of discovering these issues. Therefore, it could be argued that any overrepresentation is counterbalanced by those that avoided this study out of fear of their mental health and quality of life post-concussion.

4.7 Practical Implications

The present study suggests that physical pain is more responsible for poor mental health and reduced quality of life than concussion history. As physical pain levels increase, depression and anxiety symptoms increase, and quality of life decreases while concussion history has no impact on these outcomes. Therefore, with this knowledge we can develop more efficient strategies for protecting mental health and supporting quality of life. Based on the current findings, it would appear unnecessary to be concerned with mental health and quality of life post-concussion if not in any physical pain, which opposes what is commonly known.

Instead, there may be other negative outcomes associated with concussion that are of more concern, such as cognitive impairment (Bleiberg et al., 2004; Guskiewicz et al., 2005).

4.8 Conclusions and Future Directions

The present study addresses an issue in concussion research in that the role of physical pain is often overlooked, and vice versa. There are many studies that conclude concussion history is associated with poor mental health and reduced quality of life (Doroszkiewicz et al., 2021; Gard et al., 2020; Hind et al., 2021; Turner et al., 2017; Voormolen et al., 2019 Yrondi et al., 2017), without considering the role of physical pain. Similarly, there are many that report physical pain to have this same influence (Ishak et al., 2018; Niv & Kreitler, 2001; Walker & Marchant, 2020; Walker & McKay, 2022) and overlooking the impact of concussion. In the studies investigating concussion, it may be that physical pain led to mental health decline and reduced quality of life but was not captured and vice versa in the pain studies. Therefore, by assessing these factors simultaneously, we are the first to determine that physical pain is more responsible for mental health decline and reduced quality of life than concussion. Not only does this indicate that those in pain are more likely to display negative changes to their mental health and quality of life but suggests that other negative impacts of concussion ought to be explored. Cognitive impairment is also associated with both concussion (Gonzalez et al., 2021; Kodali & Fisqua, 2021) and physical pain (Hageman et al., 2014; Moriarty et al., 2016), and assessing these simultaneously like in the present study is an important next step.

Traditionally, poor mental health (Kerr et al., 2014; Rice et al., 2018), impaired cognition (Guskiewicz et al., 2005; Pearce et al., 2018) and low quality of life (Popov et al., 2022) are reported alongside concussion history. However, this chapter compliments the findings from

Chapter 3, in that physical pain has a detrimental impact to mental health and quality of life and poses that the role of concussion history may be overstated due to physical pain infrequently recorded. As we report that physical pain may be more responsible for poor mental health and reduced quality of life than concussion history, this informed Chapter 5 whereby cognition measures were also included to determine whether physical pain or concussion history are associated with cognitive impairments.

Chapter 5: Study 3 - Providing a clearer insight into how concussion and physical pain impact mental health, cognition, and quality of life[1]

5.1 Abstract

Sport-related concussion (SRC) and physical pain are both associated with poor mental health, impaired cognition, and reduced quality of life. Despite SRC and physical pain often co-occurring, there is little research that investigates these two factors together, and therefore it is difficult to conclude which of these contributes to the negative outcomes associated with them. Therefore, the present study aimed to investigate the effect of SRC and physical pain on mental health, cognitive ability, and quality of life. Depression was measured using the Center for Epidemiological Studies, anxiety was assessed using the State-Trait Anxiety Inventory while the SF-12 recorded health-related quality of life. A trail making task (TMT) assessed cognitive flexibility of participants. Analysis of 83 participants (43 concussed) revealed that SRC led to reduced accuracy on TMT(A) and (B), whereas physical pain was responsible for poorer mental health and reduced quality of life. This study highlights the influence that SRC has on cognitive ability and the impact that physical pain has on mental health and quality of life. With this information, we are better placed to predict the negative consequences of SRC and physical pain and therefore tailor support accordingly.

Keywords: Depression, Anxiety, Cognitive Flexibility, Quality of Life, Concussion, Physical Pain

[1] An adapted version of this chapter has been published in *Journal of Concussion*.

The introduction section below is a summary of past research that was presented in Chapter 1.

5.2 Introduction

Sport-related concussion (SRC) has become a widely investigated area in recent years, with many sport-related activities involving high energy events that can expose athletes to direct and indirect traumas and increase their risk of injury (Chambers et al., 2015; Póvoas et al., 2014). Consequences of SRC have been identified, with poorer mental health (Hoyle, 2020; Mrazik, 2021), impaired cognition (Gonzalez et al., 2021; Kodali & Fisqua 2021), and reduced quality of life (Doroszkiewicz et al., 2021; Walton et al., 2021), among the most prevalent outcomes. Although physical pain often accompanies SRC (Mollayeva et al., 2017; Provance et al., 2020), surprisingly few studies incorporate this factor into SRC research. Therefore, the relationship between SRC and physical pain and these three broad outcomes warrants investigation. By better understanding how SRC and physical pain relate to mental health, cognitive ability, and quality of life, we are better able to support athletes that have sustained SRC, experiencing physical pain, or both.

Depression is one of the most researched mental health disorders, likely due to its high prevalence, with 3.8% of the general population suffering from depression (WHO, 2023). However, higher rates are reported in athletes that have (Rosenthal et al., 2014; Wolanin et al., 2016) and have not sustained SRC (Walker & Marchant, 2020; Yang et al., 2007). These elevated depressive symptoms are also found in student athletes who report higher levels of physical pain (Walker & Marchant, 2020; Walker & McKay, 2022). Given the great comorbidity between depression and anxiety, it is predictable that elevated scores of anxiety are also often found in those that have sustained SRC (Yang et al., 2015) and experiencing physical pain (Elbinoune et al., 2016; Gureje, 2008; Walding, 1991). Therefore, as SRC and physical pain are likely to co-occur (Mollayeva et al., 2017; Provance et al., 2020) and both are found to negatively impact depression and anxiety, it is important to understand which contributes more to these outcomes.

Cognitive flexibility involves the ability to adjust to change in task demands or priorities (Diamond, 2013) and is therefore important for athletes with evidence that cognitive flexibility levels of team athletes are higher than those of individual athletes (Aslan, 2018). Aslan (2018) suggests this could be due to individual sports requiring less cognitively than team sports. Team sports tend to be contact sports such as rugby, football, and hockey whereby SRC is likely (Harmon et al., 2019), and as SRC negatively impacts cognitive flexibility (Hume et al., 2017; Wilmoth et al., 2019), this threatens optimal performance (Aslan, 2018) as well as exacerbating other negative consequences of SRC. Therefore, it is necessary to protect athletes from sustaining SRC and the impact this can have on cognitive flexibility. The role of physical pain on cognitive flexibility is still unclear with many studies examining chronic pain in humans (Hageman et al., 2014; Moriarty et al., 2016) and animals (Cowen et al., 2018). Despite the literature unclear on the role that physical pain has on cognitive flexibility, there are studies linking physical pain with impairments to other areas of cognition (Gonzalez et al., 2021; Kodali & Fisqua 2021). As these studies did not account for SRC, it may be that impaired cognition was misattributed to physical pain, and therefore assessing both simultaneously is warranted.

Considering there is evidence that SRC and physical pain are associated poorer mental health (Rosenthal et al., 2014; Wolanin et al., 2016; Yang et al., 2015) and cognitive impairment (Hume et al., 2017; Wilmoth et al., 2019), it is unsurprising that these factors are also associated with reduced quality of life (Gard et al., 2020; Niv & Kreitler, 2001). It is possible that the two broad outcomes could negatively impact quality of life. For example, impaired cognition leading to individuals struggling to complete daily tasks could negatively impact quality of life. Likewise, not being able to compete at a sporting level that one once could, can lead to poorer mental health and quality of life. However, even if these examples did explain reduced quality of life in athletes, it is still unclear whether this is due to SRC or physical pain, with evidence that both negatively impact quality of life (Ponsford et al., 2019; Samadi et al., 2021; Vaegter et al., 2021; Voormolen et al., 2019), and therefore this warrants further exploration.

Although there is evidence that SRC negatively impacts mental health such as depression (Rosenthal et al., 2014; Wolanin et al., 2016) and anxiety (Yang et al., 2015), areas of cognition such as cognitive flexibility (Hume et al., 2017; Wilmoth et al., 2019), and quality of life (Gard et al., 2020; Ponsford et al., 2019; Voormolen et al., 2019), the role that physical pain has on these outcomes is still ambiguous. This is due to evidence that physical pain can also lead to poorer mental health (Walker & Marchant, 2020; Walker & McKay, 2022), impaired cognition (Hageman et al., 2014; Moriarty et al., 2016), and reduced quality of life (Samadi et al., 2021; Vaegter et al., 2021). Although SRC and pain are often experienced simultaneously (Mollayeva et al., 2017; Provance et al., 2020), and athletes are among the most at-risk of sustaining both, the two contributing factors are rarely examined in conjunction in the literature. Therefore, the present study aims to address this gap in the literature, as learning which factor affects each outcome will allow better support for athletes that have sustained SRC, are experiencing physical pain, or both.

5.3 Method

Participants

Forty-three post-concussed participants were compared with 40 non-concussed participants. The total sample completed questionnaires measuring depression and anxiety symptoms as well as quality of life, and a trail making task designed to measure cognitive flexibility.

Participants were recruited via the online departmental recruitment system within the university, advertisements on social media platforms LinkedIn and Twitter as well as word of mouth. Men and women over 18 years of age were welcomed to take part in the study. For those that had sustained concussion, a minimum of 28 days must have passed before taking part in this study to avoid exacerbating post-concussion symptoms due to the surveys being displayed on a computer screen. Those that had sustained concussion < 28 days were ineligible to take part until this period had elapsed. Post-concussed participants had sustained SRC between 1 and 48 months (*M* = 21.38, *SD* = 14.92) prior to participation with incidences ranging between 1 and 12 (*M* = 3.88, *SD* = 3.01). Further information of participants is presented in Table 1.

Sample size calculations

Sample size was calculated using G*Power 3.1.9.7. A priori calculations indicated that 84 participants were required (across the two groups) to achieve adequate power (β =0.95) to detect an effect size of *f* = 0.4 (large effect size) at α = 0.05. Therefore, the sample in this study falls one short to achieve this level of power. Post-hoc calculations were conducted to compute the actual power achieved with the sample obtained (β = 0.949) which highlighted the sample was not underpowered. A large effect size was used in calculations due to the time difference between variables (SRC history being 28+ days ago compared with physical pain in the past week).

Table 1. Participant characteristics

		Age				*N*			
		n	*M*	*SD*	*p*	SRC	Non-SRC	Total	*p*
Sex	Male	50	24.22	4.85	.604	35	15	50	.001
	Female	33	23.55	6.98		8	25	33	
Athlete Status	Athlete	50	24.10	4.87	.775	38	12	50	.001
	Non-athlete	33	23.73	6.96		5	28	33	
SRC History	Yes	43	23.51	4.74	.474	43	-	43	-
	No	40	24.43	6.71		-	40	40	
Depressed Categorisation	Yes	43	23.23	4.66	.240	24	19	43	.455
	No	40	24.73	6.72		19	21	40	

Measures

Refer to Chapter 2 for below measures:

- General Information Questionnaire (GIQ)
- Numeric Rating Scale (NRS-11; Downie et al., 1978)
- Center for Epidemiological Studies Depression Scale (CESD; Radloff, 1977)
- State-Trait Anxiety Inventory (STAI; Speilberger et al., 1970)
- Health Related Quality of Life: SF-12 (SF-12; Ware et al., 1996)
- TMT: The Trail Making Task (TMT; Reitan, 1955)

Reliability Statistics

Reliability statistics was calculated by conducting a Cronbach's Alpha. Analyses revealed internal consistency scores of α = .91 for CESD, α = .95 for STAI (state), α = .94 for STAI (trait) which are all considered excellent (Sharma, 2016) The SF-12 bore an internal consistency score of α = .81 which Sharma (2016) describes as a good score.

Data Analysis

Correlations were run between SRC history, mental health, quality of life, cognitive flexibility, and physical pain, isolated and when controlling for physical pain. A MANOVA and MANCOVA investigated the difference in cognitive flexibility, depression, anxiety, and quality of life between those that have and have not sustained sport-related concussion; one with and one without controlling the effect of physical pain. It was predicted that those that have sustained sport-related concussion would produce lower accuracy scores and higher reaction times scores on the cognitive flexibility task, elevated depressive and anxiety symptoms and lower scores of quality of life, as well as physical pain covarying significantly.

Refer to Chapter 2 for information regarding procedure and ethics.

5.4 Results

Assumptions

MANCOVA assumes that the independent variables are categorical, and the dependent variables are continuous (Finch, 2005). In this study, the independent variable was SRC history (yes/no) and therefore this is a categorical variable. Dependent variables were scores of depression, state-trait anxiety, quality of life and accuracy and response time on a cognitive flexibility task which were recorded on a scale, and therefore were continuous. Covariates can be either continuous, ordinal, or dichotomous, so the continuous recording of physical pain on a Likert scale was acceptable here and the level and measurement of variables assumption was adhered to in this study. Correlational analysis was used to measure assumptions of multicollinearity and relationships between covariate and dependent variables. Here we identified that there was an absence of multicollinearity as correlations were all below $r = .90$, guidelines that Tabachnick & Fidell (2012) suggest which satisfies these two assumptions. Normality was tested using Shapiro-Wilk analysis whereby it was revealed that much of the data was normally distributed ($p > .05$), but some were found to be non-normal ($p < .05$). However, this violation has a limited impact on type I error rate for MANOVA (Everitt, 1979).

Correlations

Correlation analysis was run on multiple variables; SRC history, depression, anxiety, cognitive flexibility, quality of life and physical pain, with and without physical pain as a covariate. Results are described in Table 2.

Table 2. Correlations between SRC history and mental health, cognitive flexibility, and quality of life with and without controlling for physical pain

Control Variables		SRC	Depression	State-anxiety	Trait-anxiety	Quality of Life	TMT(A) Accuracy	TMT(A) RT	TMT(B) Accuracy	TMT(B) RT	TMT Accuracy Difference	TMT RT Difference	Physical Pain
None	SRC	-	-	-	-	-	-	-	-	-	-	-	-
	Depression	-.097	-	-	-	-	-	-	-	-	-	-	-
	State-anxiety	-.055	**.762****	-	-	-	-	-	-	-	-	-	-
	Trait-anxiety	.008	**.789****	**.787****	-	-	-	-	-	-	-	-	-
	Quality of Life	.102	**-.777****	**-.701****	**-.750****	-	-	-	-	-	-	-	-
	TMT(A) Accuracy	**.230***	.066	.132	.089	-.166	-	-	-	-	-	-	-
	TMT(A) RT	-.059	.075	-.008	.047	-.033	-.043	-	-	-	-	-	-
	TMT(B) Accuracy	**.321****	-.122	-.111	.010	.121	**.419****	.021	-	-	-	-	-
	TMT(B) RT	.125	.185	.090	.206	**.256***	.022	**.436****	-.122	-	-	-	-
	TMT Accuracy Difference	-.049	-.148	-.212	-.091	.201	**-.824****	.060	.170	-.100	-	-	-
	TMT RT Difference	-.161	-.067	-.079	-.112	.167	-.063	**.706****	.118	**-.329****	.142	-	-
	Physical Pain	-.022	**.301****	**.277***	**.236***	**-.328****	-.040	-.062	-.040	.185	.019	-.210	-
Physical Pain	SRC	-	-	-	-	-	-	-	-	-	-	-	-
	Depression	-.095	-	-	-	-	-	-	-	-	-	-	-
	State-anxiety	-.051	**.741****	-	-	-	-	-	-	-	-	-	-
	Trait-anxiety	.014	**.774****	**.772****	-	-	-	-	-	-	-	-	-
	Quality of Life	.101	**-.752****	**-.673****	**-.733****	-	-	-	-	-	-	-	-
	TMT(A) Accuracy	**.229***	.082	.149	.102	-.137	-	-	-	-	-	-	-
	TMT(A) RT	-.061	.098	.010	.064	-.057	-.046	-	-	-	-	-	-
	TMT(B) Accuracy	**.320****	-.116	-.104	.020	.114	**.418****	.019	-	-	-	-	-
	TMT(B) RT	.132	.138	.041	.170	-.211	.030	**.456****	-.117	-	-	-	-
	TMT Accuracy Difference	-.049	-.161	**-.226***	-.098	**.219***	**-.824****	.061	.171	-.105	-	-	-
	TMT RT Difference	-.169	-.004	-.022	-.066	.106	-.073	**.711****	.112	**-.302****	.149	-	-
	Physical Pain	-	-	-	-	-	-	-	-	-	-	-	-

Note - * - $p < .05$ ** - $p < .01$

MANOVA/MANCOVA

Results from the MANOVA (without controlling for physical pain) and the MANCOVA where physical pain was added as a covariate are displayed in Table 3. Descriptive statistics are presented below in Table 4 to aid the interpretation of the findings from Table 3.

Table 3. MANCOVA depicting the influence of SRC history on cognitive flexibility, depression, anxiety, and quality of life with pain as a covariate				
	df	η_p^2	*F*	*p*
MANOVA				
SRC				
TMT (A) Accuracy (%)	**1, 81**	**.053**	**4.524**	**.036***
TMT (A) Reaction Time (s)	1, 81	.004	0.286	.594
TMT (B) Accuracy (%)	**1, 81**	**.103**	**9.296**	**.003****
TMT (B) Reaction Time (s)	1, 81	.016	1.295	.258
TMT Accuracy Difference	1, 81	.002	0.198	.658
TMT Reaction Time Difference	1, 81	.026	2.154	.146
Depression	1, 81	.009	0.774	.381
State-Anxiety	1, 81	.003	0.243	.623
Trait Anxiety	1, 81	.000	0.005	.947
Quality of Life	1, 81	.010	0.857	.357
MANCOVA				
SRC				
TMT (A) Accuracy (%)	**1, 80**	**.053**	**4.441**	**.038***
TMT (A) Reaction Time (s)	1, 80	.004	0.297	.587
TMT (B) Accuracy (%)	**1, 80**	**.103**	**9.146**	**.003****
TMT (B) Reaction Time (s)	1, 80	.017	1.415	.238
TMT Accuracy Difference	1, 80	.002	0.192	.662
TMT Reaction Time Difference	1, 80	.029	2.363	.128
Depression	1, 80	.009	0.730	.395
State-Anxiety	1, 80	.003	0.205	.652
Trait Anxiety	1, 80	.000	0.015	.902
Quality of Life	1, 80	.010	0.819	.368
Physical Pain				
TMT (A) Accuracy (%)	1, 80	.001	0.106	.746
TMT (A) Reaction Time (s)	1, 80	.004	0.319	.574
TMT (B) Accuracy (%)	1, 80	.001	0.098	.755
TMT (B) Reaction Time (s)	1, 80	.036	2.962	.089
TMT Accuracy Difference	1, 80	.000	0.025	.875
TMT Reaction Time Difference	1, 80	.047	3.927	.051
Depression	**1, 80**	**.090**	**7.904**	**.006****
State-Anxiety	**1, 80**	**.076**	**6.613**	**.012***
Trait Anxiety	**1, 80**	**.056**	**4.745**	**.032***
Quality of Life	**1, 80**	**.107**	**9.607**	**.003****

*- $p < .05$, **- $p < .01$

Note – significant results are highlighted in **bold**

Table 4. Descriptive statistics of cognitive flexibility, depression, anxiety, and quality of life by SRC history				
	SRC		Non-SRC	
	M	*SD*	*M*	*SD*
TMT (A) Accuracy (%)	**94.51**	**12.22**	**98.70**	**2.46**
TMT (A) Reaction Time (s)	45.90	28.54	43.30	11.72
TMT (B) Accuracy (%)	**95.14**	**6.53**	**98.50**	**2.51**
TMT (B) Reaction Time (s)	49.21	13.64	53.33	19.04
TMT Accuracy Difference	0.63	11.25	-0.20	3.62
TMT Reaction Time Difference	33.12	24.49	10.03	15.96
Depressive Symptoms	**18.60**	**11.33**	**16.60**	**9.23**
State-Anxiety Symptoms	**40.37**	**13.01**	**39.00**	**12.28**
Trait Anxiety Symptoms	**45.05**	**12.92**	**45.25**	**12.03**
Quality of Life Scores	**23.65**	**5.93**	**24.83**	**5.59**
Physical Pain	2.77	2.06	2.68	2.18

Note – significant results are highlighted in **bold**

Post-Hoc Tests

Following this, the assumption of homogeneity of regression slopes was tested, as this is vital when using MANCOVA analysis. The interaction term between SRC history and physical pain had a significant effect on TMT(B) accuracy (p = .032) violating the assumption of homogeneity of regression slopes and therefore results for this variable should be inferred with caution. However, this assumption has been adhered to for all other variables ($p > .05$), indicating that we can accept what has been found in the main analysis for these factors.

5.5 Discussion

The present study aimed to identify the role that SRC and physical pain have in conjuncture on mental health, cognitive ability, and quality of life. Initially, our analysis revealed that SRC negatively impacted cognitive flexibility performance, with lesser accuracy recorded on both aspects of a trail making task. When accounting for physical pain, we found the same results regarding SRC and cognitive flexibility, but also that physical pain was associated with depression, state-trait anxiety, and quality of life. Therefore, despite literature that links both SRC and physical pain with poor mental health (Hoyle, 2020; Mrazik, 2021; Walker & Marchant, 2020; Walker & McKay, 2022), cognitive impairment (Gonzalez et al., 2021; Kodali & Fisqua, 2021), and reduced quality of life (Doroszkiewicz et al., 2021; Samadi et al., 2021; Vaegter et al., 2021; Walton et al., 2021), a more nuanced explanation would be that SRC is responsible for cognitive impairment and physical pain contributes to poor mental health and reduced quality of life.

SRC and impaired cognitive flexibility have been linked before (Hume et al., 2017; Wilmoth et al., 2019), however, the role that physical pain has on cognitive flexibility is unclear. This is because studies assessing chronic pain in humans (Hageman et al., 2014; Moriarty et al., 2016) and animals (Cowen et al., 2018) are commonplace. Many athletes and non-athletes (Ferreira et al., 2018) live daily with acute physical pain, however, the effect of this on cognitive flexibility, to our knowledge, has not yet been examined. This study addresses this shortfall and provides evidence that acute physical pain has no detrimental impact to cognitive flexibility, which has positive practical implications given the many negative impacts of physical pain. From a sporting perspective, Vestberg et al. (2012) have shown that professional and semi-professional football players had significantly better performances in switching tasks like TMT. Similar findings have been reported in rugby (Faubert, 2013), basketball (Cortis et al., 2011) and tennis (Shim et al., 2005). This signifies the importance of task switching ability and cognitive flexibility for optimal sporting performance. Therefore, it is reassuring that physical pain is not associated with impairment to cognitive flexibility but concerning that SRC history is.

Although it is thought cognitive impairment subsides shortly after concussion (Lifshitz et al., 2007), and some studies suggest cognitive impairments resolve within a week (Bleiberg et al., 2004; Delaney et al., 2002), this study indicates that the effects can last up to four years following concussion. Our sample consisted of athletes that had sustained concussion between 1 and 48 months prior to their participation with a large variance as highlighted by the standard deviation. Therefore, cognitive flexibility may be impaired following a concussion that never returns to baseline (however, pre-morbid assessments were not conducted in this study). Cognitive flexibility is important for various reasons within (Mujika et al., 2018) and outside of sport (Diamond, 2013; Roy & Dugal, 1998), and therefore this study highlights the importance of avoiding SRC.

Not only does this study highlight the importance of avoiding SRC, but also of preventing physical pain where possible. Where SRC history is associated with poorer cognitive flexibility, physical pain appears to contribute to poorer mental health (depression and anxiety) and reduced quality of life. These findings support previous literature that have found physical pain to be associated with poor mental health (Walker & Marchant, 2020; Walker & McKay, 2022) and reduced quality of life (Gard et al., 2020; Niv & Kreitler, 2001). However, this study brings into question studies that conclude concussion is responsible for negative changes to mental health and quality of life, that do not account for physical pain (Doroszkiewicz et al., 2021; Hoyle, 2020; Mrazik, 2021; Walton et al., 2021).

As concussion and physical pain often co-exist (Mollayeva et al., 2017; Provance et al., 2020), it could be that previous studies have misattributed these negative consequences to concussion, where in fact physical pain may be the responsible factor. Therefore, from the present study, it appears that SRC is associated with cognitive impairment and physical pain is responsible for poor mental health and reduced quality of life.

5.6 Practical Implications

This main findings from this study are that SRC is linked with poorer cognitive flexibility, even long after the event, and acute physical pain has a negative impact on mental health and quality of life. These findings are concerning given prior evidence that physical activity appears to promote cognitive flexibility performance (Dupuy et al., 2018; Ludyga et al., 2020). From this study, it seems physical activity is not enough to offset the effects that SRC has on cognitive ability. Given that age between concussion groups were not significantly different, it is unlikely that age was a confound in this sample whereby changes in cognitive flexibility could be attributed. Additionally, as both groups are young, it is alarming that concussion has had a negative long-lasting influence on cognitive ability. Based on these findings, sports coaches, especially in contact sports where concussion is prevalent (Bakhos et al., 2010), should incorporate cognitive flexibility tasks within training sessions to combat cognitive flexibility changes. There is evidence that cognitive training can slow down cognitive decline (Husseini et al., 2016), and as there are benefits to efficient cognitive flexibility within (Mujika et al., 2018) and outside of sport (Diamond, 2013; Roy & Dugal, 1998), this is highly beneficial for athletes and sports teams.

Additionally, this study links physical pain with reduced quality of life, with the reasons for improving quality of life obvious. Providing athletes with pain questionnaires to complete regularly may benefit athletes and their teams. Physical pain has been associated with depression (Walker & Marchant, 2020), and depression has in-turn been linked with lower quality of life (Diaz et al., 2019). Therefore, pain questionnaires may indicate those at risk of reduced quality of life. There is also evidence that female athletes will experience depression at lower levels of physical pain than male athletes (Walker & McKay, 2022), and therefore coaches should consider this. Therefore, regular anonymous pain questionnaires would aid the identification of struggling athletes and in-turn supporting those that require it.

5.7 Limitations

Although the present study has a relatively low sample size it was not underpowered as highlighted by the sample size calculations. Therefore, the risk of type II error was low. There is, however, a risk of self-selection bias due to the voluntary nature of our recruitment. As the study was advertised as exploring the impact that SRC has on mental health, cognitive ability, and quality of life, post-concussed athletes that have noticed deterioration of these three factors may be over-represented in this sample. This could explain the high prevalence of depression in the sample regardless of concussion history, as well as impaired cognition and lower quality of life in the post-concussed sample. Additionally, data collection commenced largely during COVID-19 restrictions, and as these restrictions were found to be detrimental to mental health (Banks et al., 2021), which could have influenced results regarding mental health and quality of life regarding SRC history, as all would have been subjected to these restrictions. However, that confound was unavoidable and future research should continue to investigate the impact that SRC has on mental health and quality of life.

Another issue was the difference in timeframe between SRC history and physical pain. SRC history was recorded as anyone that had previously sustained SRC in the past four years. By contrast, physical pain scores were recorded as to the level of pain experienced in the week preceding the study. Therefore, this disparity in timeframe may be reflected in the present findings and could explain why physical pain is associated with mental health and quality of life. However, while research tends to suggest cognitive impairment lasts for around a week (Bleiberg et al., 2004; Delaney et al., 2002), this study suggests that these effects persist over a longer period, and future studies should investigate the mid to long-term effects of SRC on cognitive ability.

Importantly, it must be noted that participants completed questionnaires and the cognitive task just once and were then separated into concussion groups based on their reporting of their SRC history. Due to this, we cannot know the cognitive abilities of the concussed group prior to their concussion. It is possible that this group would have always performed less accurately on the cognitive flexibility task, regardless of their concussion, and that we are falsely attributing this to the concussive event. However, our approach is typical within concussion literature due to practical issues associated with pre-morbid assessments. Therefore, the results still hold value, despite this limitation.

That said, the usual approach within concussion literature is to match participants for potential confounds so that the impact of SRC is evident. However, in this study, there was a significant difference between the biological sex of participants and their status as an athlete. As there are significant differences between these variables, they could both act as confounds when assessing the negative impacts of SRC. In this study, there were more males than females that had sustained SRC, and therefore the results here are perhaps more applicable to males. Moreover, athlete status is unlikely to effect on the outcomes we were interested as SRC, by nature, is only possible in athletes. In fact, some athletes could withdraw from sport due to sustaining SRC and experiencing its' negative consequences (i.e., there were 5 participants that were non-athletes that has sustained SRC) and would therefore be classed as a non-athlete in this study. Therefore, although this limitation should be considered when inferring the results, it is perhaps better to evade this misclassification of athlete status in the analysis.

5.8 Conclusions and Future Directions

The present study attempted to investigate the impact of SRC and physical pain on mental health, cognitive ability, and quality of life. Despite what is often reported (Bleiberg et al., 2004; Delaney et al., 2002), SRC appears to have a long-lasting negative impact on cognitive ability. The SRC group performed significantly worse on TMT (A) and (B) than the non-SRC group with and without controlling for physical pain, indicating that SRC is responsible for this reduced accuracy. It is noteworthy that this effect was twice as strong for TMT(B) than (A). Additionally, physical pain was significantly associated with poor mental health and reduced quality of life, supporting previous literature that deems this to be the case (Gard et al., 2020; Niv & Kreitler, 2001). The effect on quality of life was stronger than any effect on mental health measures, and just under twice as strong as the effect on trait-anxiety. Given what we know about the link between physical pain and depression (Walker & Marchant, 2020; Walker & McKay, 2022), and depression and quality of life (Diaz et al., 2019), it is sensible to treat them similarly. Sports teams could utilise pain questionnaires to identify vulnerable athletes that may require emotional support.

This chapter adds further evidence to acute physical pain having a negative influence on mental health and quality of life. Moreover, this chapter shows how SRC history is associated with cognitive impairments using a TMT, which is what would be expected (McGowan et al., 2018). However, one of the drawbacks of the current literature is understanding how the outcomes may change over time. Many researchers have investigated the effects of concussion soon after the event (Bleiberg et al., 2004; Hammeke et al., 2013; McCrea et al.,

2003) and many have assessed these outcomes in retired sportspeople of contact sports (Guskiewicz et al., 2005; Hart et al., 2013; Hume et al., 2017; Montenigro et al., 2017). We wanted to uncover what occurs in between these two time-points and how these outcomes change over time which is what Chapter 6 aimed to do.

Chapter 6: Study 4 - How does concussion impact mental health, cognitive ability, and quality of life over time?

6.1 Abstract

The present study investigated the influence of concussion on mental health, cognitive ability, and quality of life over time. While these post-concussive outcomes are well-documented, the long-term consequences need more exploration so to better support athletes which is pertinent given the influence of physical pain on these outcomes. Fifty-six post-concussed participants were tested at two occasions with between 6-8 months interval between testing (43 participants at T1 (33 male) and 13 participants at T2 (8 male)). Participants completed mental health and quality of life questionnaires, and a cognitive battery. It was found that concussion appeared to negatively impact on participants' accuracy on a cognitive flexibility task in the T2 measurement, but their speed had improved. This discrepancy in performance may be due to a possible speed-accuracy trade-off. Physical pain was also found to be associated with poor mental health and reduced quality of life. The findings of this study highlight some of the issues associated with remote cognitive testing as well as the importance of obtaining physical pain data from sportspeople to predict their emotional state and make decisions on what support is needed.

Keywords: Concussion, Physical Pain, Mental Health, Cognitive Ability, Quality of Life

The introduction section below is a summary of past research that was presented in Chapter 1.

6.2 Introduction

Given that concussion is common in contact sports (Bakhos et al., 2010) there is a growing concern for athletes that engage in these sports. Therefore, much of sport-related concussion (SRC) research has sought to examine the acute effects and recovery time of concussion (Buckley et al., 2016; McCrea et al., 2003; Williams et al., 2015) so to inform treatment (Schneider et al., 2013) and return-to-play protocol (Kissick & Johnston, 2005; Lovell et al., 2004). While understanding recovery periods and facilitating return-to-play is important for athletes as competing forms a large part of their social identity (Haslam et al., 2020), it is vital to know the lived experience of those that have sustained concussion. Poor mental health (Kerr et al., 2014; Kontos et al., 2016; Rice et al., 2018), impaired cognition (Bleiberg et al., 2004; Guskiewicz et al., 2005; McInnes et al., 2017), and reduced quality of life (Emanuelson et al., 2003; Gard et al., 2020; Popov et al., 2022) are some of the most common outcomes of concussion and have been repeatedly linked, however, how these are affected and how they may change over time remains unknown.

The work that has been conducted on these three negative post-concussion outcomes has given greater insight into providing athletes with the knowledge of what signs and symptoms to expect following such an event. Moreover, it has improved provision of immediate and appropriate care for the victim in the event of a head injury. Naturally, the acute phase of concussion is most often investigated due to the visibility of post-concussion symptoms. The impact of this research can be seen in recovery guidelines, such as avoiding bright lights, given evidence that this can exacerbate post-concussion symptoms (Abusamak & Alrawashdeh, 2022; Likova & Tyler, 2018). However, while much of the literature links concussion history with poor mental health, cognitive impairment, and reduced quality of life, it is difficult to pin-point when this occurs, and therefore if, and when this subsides.

Stein et al. (2019) are among those that have come closest to this when assessing the risk factors of post-traumatic stress disorder (PTSD) and Major Depression Disorder (MDD) in those that were evaluated for mild traumatic brain injury (mTBI) in an emergency department. Participants completed the Patient Health Questionnaire-9 (PHQ-9; Kroenke et al., 2010) at baseline which was shortly after being seen in the emergency room, and again at 2 weeks, 3-, 6-, and 12-months post-injury. It was found that over 21% of people who had experienced concussion reported mental health concerns six months after their injury, and others found similar levels of major depression persisting up to a year or more after. This demonstrates that mental health issues can persist long after the concussive event, however, as described in Chapter 1, the CESD is perhaps the most applicable tool for assessing depressive symptoms in post-concussed samples and therefore future studies should favour this tool.

While Stein et al. (2019) show how mental health issues can persist post-concussion, this has not been done for cognitive ability. Instead, much of the literature has examined the acute phase (Bleiberg et al., 2004; Hammeke et al., 2013; McCrea et al., 2003) such as Bleiberg et al. (2004) that assessed cognitive faculties up to 14 days after concussion. Conversely, there are studies that link recurrent concussion with later-life cognitive impairment (Guskiewicz et al., 2005; Hart et al., 2013; Hume et al., 2017; Montenigro et al., 2017), by grouping number of concussions sustained and analysing their cognitive ability. It can be argued that there is a large period between these two time-points where individuals are living with the negative consequences of concussion. Therefore, research ought to examine the influence of concussion on cognitive ability far beyond the 14-day mark and far before retirement of professional athletes. By understanding how cognitive ability changes over time following concussion, we are better placed to support these individuals in potentially alternate ways at different points post-concussion.

Pieper and Garvan (2014) can be credited for assessing quality of life at multiple time-points following concussion. In their sample of children that sustained concussion, pre-injury health-related quality of life was compared with their health-related quality of life at 1, 3, 6 and 12 months post-injury. However, no differences were found between any time-points from children reports, and only lower physical health decline at 6 months that had resolved by 12 months based on parent reports. These are difficult methodological issues to overcome with a non-adult sample. That said, Emanuelson et al. (2003) had previously investigated quality of life using the Health-Related Quality of Life SF-36 (Ware et al., 1994) in a sample aged 16-60 years old, at 3 weeks, 3 months, and 12 months post-injury. It was reported that SF-36 results were lower at 3 months than at 3 weeks after injury demonstrating a decline in quality of life beyond the initial recovery from concussion. Given the more recently developed SF-12 is often reported to be an improved measure of quality of life (Müller-Nordhorn et al., 2004; Wee et al., 2008) these findings ought to be replicated with the now validated SF-12. Moreover, the authors also concede that the study does not account for prolonged distress, coping problems and psychosocial sequalae that can be evident some years following concussion. This further highlights the need to simultaneously investigate mental health, cognitive ability, and quality of life, as it is plausible that a decline in any can impact on the others.

Though there is evidence that concussion is linked to poor mental health (Kerr et al., 2014; Kontos et al., 2016; Rice et al., 2018), impaired cognition (Bleiberg et al., 2004; Guskiewicz et al., 2005; McInnes et al., 2017), and reduced quality of life (Emanuelson et al., 2003; Gard et al., 2020; Popov et al., 2022), physical pain is also heavily linked with these negative outcomes (Niv & Kreitler, 2001; Gard et al., 2020; Walker & Marchant, 2020;

Walker & McKay, 2022). As concussion and physical pain often co-exist (Mollayeva et al., 2017; Provance et al., 2020), it is necessary to investigate the two simultaneously and tease apart their impact in isolation as well as combined, especially when assessing how these outcomes change over time as acute pain is likely to influence these impacts.

The existing literature provides good evidence of the negative impact that concussion can have on mental health, cognitive ability, and quality of life as well as the necessity of assessing physical pain alongside concussion. However, what is not yet understood is how these three outcomes change over time alongside acute physical pain. Understanding how these outcomes change over time post-concussion is key, to better inform the care for these athletes. At present, care for athletes is common in the acute phase of recovery, with return-to-play protocol usually seizing any care for the athlete. With the knowledge that mental health, cognitive ability, and quality of life are under threat post-concussion, it is crucial to provide care to post-concussed athletes. However, this can only be done effectively by understanding how these outcomes vary across time. Therefore, as these three outcomes are yet to be investigated across a six-month period, the present study aimed to address this gap.

6.3 Method

Participants

Fifty-six post-concussed participants (43 T1 (33 male) and 13 T2 (8 male)) took part in this study. The exact number of days between participating in T1 and T2 ranged from 177-236 (*M* = 197.38, *SD* = 15.63). All participants had sustained concussion (51 SRC, 12 NSRC, 7 both). More characteristics are described in Table 1.

Table 1. Descriptive statistics of participant characteristics						
	Total	*M*	*SD*	Total	*M*	*SD*
Number of concussions	110	3.34	2.75	8	1.09	0.30
		SRC			NSRC	
	Range	*M*	*SD*	Range	*M*	*SD*
PCSS Scores						
T1	9-105	62.48	24.35	7-87	43.14	31.10
T2	16-90	52.67	25.55	7-74	29.25	30.46
Months Since Concussion	2-134	35.05	34.72	4-219	75.25	93.29

Sample size calculations

Sample size was calculated using G*Power 3.1.9.7. A priori calculations indicated that 84 participants were required (across the two groups) to achieve adequate power (β =0.95) to detect an effect size of *f* = 0.4 (large effect size) at α = 0.05. Therefore, the sample in this study falls short of achieving this level of power. However, post-hoc calculations that computed the actual power achieved with the sample obtained (β = 0.836) which highlighted the sample was not underpowered, as 0.8 is considered the threshold for statistical power (Cohen, 2013). There is still over 83% chance of finding a statistically significant difference between T1 and T2 mental health, cognition, and quality of life if there is one. A large effect size was used in calculations due to the time difference between variables (SRC history being 28+ days ago compared with physical pain in the past week).

Measures

The following measures were used in this study: General Information Questionnaire (GIQ); Numeric Rating Scale (NRS-11; Downie et al., 1978); Center for Epidemiological Studies Depression Scale (CESD; Radloff, 1977); State-Trait Anxiety Inventory (STAI; Speilberger et al., 1970); Positive and Negative Affect Scale (PANAS; Watson et al., 1988); Health Related Quality of Life: SF-12 (SF-12; Ware et al., 1996); Royal Prince Alfred Prospective Memory Test (RPA-PMT; Radford et al., 2011); N-Back Task; Local-Global Task; Digit-

Span Forward Task; Digit-Span Backward Task; Stop-Signal Task; Colour-Stroop Task; Trail Making Task; Corsi Block Test; and Verbal Paired Associates I/II. Please refer to Chapter 2 for detailed information on each of these measures.

Apparatus

The apparatus used remain the same as described in Chapter 2. These were: E-Prime GO (Psychology Software Tools, Pittsburgh, PA); Pavlovia (Pierce et al., 2019); and Psytoolkit (Stoet, 2010; 2017).

Reliability Statistics

Reliability analyses using Cronbach's alpha revealed excellent internal consistency scores of α = .93 for PCSS, α = .92 for CESD, α = .96 for STAI (state), α = .95 for STAI (trait) and α = .90 for PANAS (negative) and good scores of α = .84 for PANAS (positive) and SF-12 (Sharma, 2016).

Data Analysis

The data with participants test scores were analysed to identify any potential confounds between T1 and T2 measurements. The potential confounds examined were age, biological sex, history of receipt of furlough, athlete status, predominant sport, hours engaged in sport per week pre/post COVID onset, most recent/highest participation level of sport, injury status, self-reported physical pain, number of SRC/NSRC sustained, recovery period, months elapsed since and PCSS scores for SRC/NSRC. A number of MANOVA and MANCOVA investigated the difference in mental health, cognition, and quality of life between T1 and T2, which were conducted six to eight months apart, one ANOVA was conducted with and one ANOVA without controlling the effect of physical pain. Any discrepancies between the outcomes of the two ANOVAs would imply a confounding effect of that variable. It was predicted that T2 scores would reveal elevated mental health symptoms reduced accuracy and heighted reaction times on cognitive tasks, and reduced quality of life scores, as well as physical pain covarying significantly.

The procedures remained the same as described in chapter 2, as did the ethical approval.

6.4 Results

Assumptions

There are several assumptions that are important for one-way MANOVA and MANCOVA (Finch, 2005). Firstly, independent variables should be categorical and dependent variables continuous. In this study, independent variables were time taking part in the study (T1/T2), and dependent variables were mental health symptoms, accuracy and response times on the cognitive battery and quality of life scores which were all continuous and therefore these assumptions were satisfied. Normality was tested using Shapiro-Wilk analysis whereby it was revealed that much of the data was normally distributed ($p > .05$), but some were found to be non-normal ($p < .05$). However, this violation has a limited impact on type I error rate for MANOVA (Everitt, 1979).

Potential Confounds

A one-way ANOVA was conducted to investigate the potential confounds between T1 and T2, to strengthen the argument that what we are assessing between T1 and T2 testing is the influence of SRC and NSRC. The potential confounds we were interested in were age, biological sex, history of receipt of furlough, athlete status, predominant sport, hours engaged in sport per week pre/post COVID onset, most recent/highest participation level of sport, injury status, self-reported physical pain, number of SRC/NSRC sustained, recovery period, months elapsed since and PCSS scores for SRC/NSRC. The ANOVA revealed no effect of these variables between T1 and T2 (all $p > .05$).

Descriptive Statistics

Descriptive statistics of mental health symptoms, cognitive ability, and quality of life scores are displayed in Appendix P. These are separated into T1 and T2 participation and show the difference between them.

MANOVA/MANCOVA

The MANOVA revealed a significant effect of time of participation (T1 or T2) on five measures of the cognitive battery which are displayed in Table 2. All other measures of the cognitive battery as well as mental health measures and quality of life found no effect of time of participation (all $p > .05$). The MANCOVA, with physical pain as a covariate, found that time of participation still had an effect on the same five measures of the cognitive battery as the MANOVA, but also that physical pain had a significant effect on all mental health and quality of life scores and two cognitive battery tasks as highlighted in Table 2. All other measures of the cognitive battery found no effect of time of participation or physical pain (all $p > .05$).

Table 2. MANOVA and MANCOVA depicting the long-term influence of concussion on mental health symptoms, cognitive ability, and quality of life scores with pain as a covariate

	df	η_p^2	*F*	*p*
MANOVA				
T1/T2				
One-Back Non-Target Accuracy	1, 54	.093	5.566	.022*
Global Stimuli Accuracy	1, 54	.078	4.544	.038*
TMT (B) Accuracy	1, 54	.091	5.438	.023*
TMT (B) RT	1, 54	.106	6.429	.014*
VPA-I Recall	1,54	.139	8.707	.005**
MANCOVA				
T1/T2				
One-Back Non-Target Accuracy	1, 53	.099	5.838	.019*
Global Stimuli Accuracy	1, 53	.074	4.207	.045*
TMT (B) Accuracy	1, 53	.101	5.929	.018*
TMT (B) RT	1, 53	.103	6.076	.017*
VPA-I Recall	1, 53	.138	8.496	.005**
Pain				
Depressive Symptoms	1, 53	.286	21.220	.000**
State-Anxiety Symptoms	1, 53	.254	18.054	.000**
Trait-Anxiety Symptoms	1, 53	.296	22.318	.000**
PANAS Positive Scores	1, 53	.112	6.681	.013*
PANAS Negative Scores	1, 53	.281	20.741	.000**
Quality of Life Total Scores	1, 53	.338	27.021	.000**
Quality of Life Physical Scores	1, 53	.164	10.382	.002**
Quality of Life Mental Scores	1, 53	.410	36.842	.000**
One-Back Target RT	1, 53	.116	6.933	.011*
Stop Trials RT	1, 53	.077	4.433	.040*

*****- $p < 0.05$, ******- $p < 0.01$

Post-Hoc Tests

Following this, the assumption of homogeneity of regression slopes was tested as this test is vital when using ANCOVA analyses. The interaction term between T1/T2 and physical pain only had an effect on the accuracy of TMT(B) trials (p = .035) and therefore these results in the main analysis should be inferred with caution as the assumption of homogeneity of regression slopes has been violated. However, the interaction term did not have an effect on any other measures in the study (all $p > .05$) and therefore the assumption of homogeneity of regression slopes has been adhered to and we can accept what has been found in the main analysis.

6.5 Discussion

The primary aim of this study was to assess whether mental health, cognitive ability, and quality of life was affected over time in those that have previously sustained concussion. Firstly, it was important to be able to control for variables that could influence scores of mental health, cognitive ability, and quality of life over time. The ANOVA that included potential confounds[2] revealed there were no significant differences in these variables between T1 and T2 participation. Therefore, it can be argued that the differences found between T1 and T2 participation are likely due to concussion. However, due to the influence of physical pain on these outcomes (Hart et al., 2003; Ishak et al., 2018; Niv & Kreitler, 2001), - which was highlighted in chapters 3-5, the role of pain was also investigated further as a covariate.

Analysis found that mental health symptoms and quality of life scores did not differ between T1 and T2 participation. However, these measures were all significantly associated with covarying pain and therefore it is important to remember that there was a negative impact on mental health and quality of life post-concussion, just that it did not differ over the time-period of the current study. There are many studies that suggest that concussion can lead to poorer mental health (Hind et al., 2021) and reduced quality of life (Popov et al., 2022), and the current study support these claims. However, as has been highlighted in chapters 3 and 4, research into this area often omits the influence of physical pain. Here we, once again dissociate the influence of concussion history with poor mental health and reduced quality of life and instead provide evidence that it is acute physical pain that is a bigger determinant of these outcomes (Walker & Marchant, 2020; Walker & McKay, 2022).

[2] Confounds included - age, biological sex, history of receipt of furlough, athlete status, predominant sport, hours engaged in sport per week pre/post COVID onset, most recent/highest participation level of sport, injury status, self-reported physical pain, number of SRC/NSRC sustained, recovery period, months elapsed since and PCSS scores for SRC/NSRC

Some cognitive abilities were also found to be impaired due to concussion. For example, accuracy on a cognitive flexibility task was worse in T2 compared with T1, indicative of impaired cognitive flexibility to switch tasks, with this unlikely to be due to practice effects (Bartels et al., 2010). That said, this may be due to them responding significantly quicker. It is therefore difficult to conclude that concussion has led to cognitive impairment over time due to low accuracy scores but that it has sped up their reaction time. Perhaps a more likely explanation is that participants during T2 were more inclined to respond as fast as possible and disregarded accuracy more so than participants in the T1 condition. This action is known as a speed-accuracy trade-off, commonly underpinned as Fitts' Law (Fitts, 1954) whereby the faster a task is carried out the less accurate the completion of the task and vice versa. This trade-off could have occurred in this study rather than there being a meaningful reduction in cognitive ability between time-points due to concussion.

Moreover, there was increased accuracy in the short-term memory task and in a different switching task during T2 participation. Alone, these results may be more indicative of type I error, as it is unlikely that concussion improves cognitive ability over time. However, the standard deviations of these measures decreased in T2, suggesting that the data are more closely related to the mean than in T1. This could be due to the lower number of participants in T2 however it could also indicate how cognitive impairment typically subsides approximately 3 months (Hall et al., 2005) following concussion. Concussion is becoming more known as a personal experience (Anderson et al., 2006) and the larger standard deviations in T1 may indicate a larger disparity of cognitive impairment whereby this seems to become more stable over time as demonstrated in T2. Therefore, the present study suggests that cognitive impairments are likely to be worse in the aftermath of the concussion and will steadily improve over time. It is also important to make athletes aware of the importance of completing the cognitive battery as accurately and quickly as possible to prevent a speed-accuracy trade-off distorting the results.

This study therefore supports what has consistently been found throughout this thesis in that physical pain appears to be more responsible for poor mental health and reduced quality of life compared to concussion history. These conclusions support previous research that has found a similar influence of physical pain on mental health (Walker & Marchant, 2020; Walker & McKay, 2022) and highlights why others may conclude concussion history to negatively impact mental health (Hind et al., 2021) and quality of life (McLeod et al., 2019) without considering the effect that physical pain has. As concussion and physical pain are likely to co-exist (Mollayeva et al., 2017; Provance et al., 2020) it could be that the effect of physical pain is being overlooked, as highlighted in chapter 3. In future, researchers should continue to investigate the two simultaneously.

6.6 Limitations

The high attrition rate (77%) cannot be ignored. Pieper and Garvan (2014) and Stein et al. (2019) reported attrition rates of 28% and 30% respectively over a six-month study period which is visibly lower than that of the current study. This could be an effect of COVID-19 restrictions in the UK as much of the T1 data collection period took place during lockdowns whereas much of the T2 data collection period did not. Bond et al. (2021) refer to an increase in leisure time and a reduction in leisure opportunities responsible for alternative means of consumption. It may be that participants had more time at their disposal to take part in research at T1 and did not during T2. That said, Emanuelson et al. (2003) reported an attrition rate of 65% over a 12-month period, and as our study used a 6-8 month-period after T1 participation, it may be that we are reporting a similar trend here and the attrition rate we report could be expected.

Despite the small sample size, the data were not underpowered, and therefore we have over four in five chances of detecting a significant effect if there is one, which is in line with Cohen's (2013) recommendations. That said, the sample of just thirteen T2 participants may explain why less was found regarding the effects of concussion on the cognitive battery. As well as that, the cognitive battery was originally planned to be administered face-to-face in the psychology labs at the Edge Hill University. Due to COVID-19 disruptions, and proximity restrictions, this was not possible. This led to the cognitive battery being administered remotely. While this was the correct thing to do for the project, allowing the collection of data from all over the UK, it does mean that the level of control during cognitive assessment was lowered. For example, participants screen size and brightness as well as the distance they were from the screen may have acted as confounds in the present study and could be as to why less was found regarding cognitive ability. That said, this was consistent across T1 and T2 and therefore any confound from this was counterbalanced. As there are still some differences between T1 and T2 participation on cognitive ability, there is value in the findings and the conclusions that cognitive ability is impaired following concussion.

Not only did the onset of the COVID-19 pandemic alter the procedure of the study, but it may have impacted the outcomes we were interested in, especially the effects of sport-related concussion and physical pain on mental health, given there is emerging evidence that COVID-19 restrictions are also associated with poor mental health (Banks et al., 2021). Participants in the present study reported engaging in less hours per week post-onset of COVID-19 (M = 3.26, SD = 3.24) than they did pre-onset (M = 7.15, SD = 4.83). There is evidence that those that reported a negative change in their exercise behaviour from before COVID-19 restrictions to during COVID-19 restrictions demonstrating poorer mental health and well-being compared to those that either had a positive or no change in exercise behaviour (Faulkner et al., 2021). Therefore, as COVID-19 restrictions appears to have encouraged a negative change in our samples' exercise behaviour, it could be that this influenced mental health in our study. Albeit an unavoidable consequence of the COVID-19 pandemic, we would argue that the importance of mental health in sport is paramount and therefore warrants investigation regardless of confounds.

Conversely, it could also be that this time away from engaging in physical activity and sporting competition protected them from exacerbated physical pain and overuse injuries. These have been found to be associated with elevated depressive symptoms (Walker & Marchant, 2020; Walker & McKay, 2022). However, pain still seems to have a negative effect on quality of life measures in this study. Given that participants are demonstrating reduced quality of life associated with pain in a time where they are likely to be experiencing less physical pain due to reduced physical activity and sporting competition suggests that the influence of pain may have been higher had the COVID-19 pandemic not reduced this playing time.

6.7 Practical Implications

Many would agree that the use of the PCSS to measure concussion symptoms is appropriate in the days and weeks following concussion. However, there would be the suggestion of recall bias when suggesting that this tool could be used beyond this point, months, and years after the concussive event. However, this study suggests that this tool could be used at these later time points as we found no difference in PCSS scores for both SRC and NSRC at T1 and T2. This suggests that recall of these events remain consistent, which is plausible given the impact it could have physically and mentally. Therefore, this study highlights the use of PCSS across longer periods of time, and generally to trust the lived experiences of participants, rather than doubting their recalling ability.

It should also be noted that all participants scored over 7 on the PCSS in this study. As <7 has previously been used as a cut-off score for return to play (Lau et al., 2011; Sicard et al., 2018) and other studies has found even non-injured athletes average a score of 5.8 on the PCSS (Iverson et al., 2003), a score of ≥7 could indicate concussion, and this has been found to be the case in our sample. Therefore, in practice, particularly amateur contact sports that often do not have health care professionals at their disposal who could identify and diagnose concussion, utilising the PCSS with the knowledge that a score of ≥7 may be symbolic of concussion could be a useful proactive step.

This study also highlights the issues with remote cognitive testing. One of the main issues involved in this study was the use of E-Prime GO for several tests in the cognitive battery. While this software was useful in allowing the study to be conducted, it does require 4GB of RAM on the participants device, limiting the number of participants that are able to take part, as not all will have access to a device with this amount of RAM. This was found to be the case and there were thirty-two willing participants that had to withdraw for this reason. Had all participants that wanted to take part could do, the findings could have been altered. Therefore, it could be that there was a quantity-quality trade-off here regarding participant numbers. While it was the correct decision to attempt to assess cognitive ability remotely in response to the COVID-19 restrictions, it may be that the quality of the data has suffered for the reasons highlighted above. Therefore, the present study may indicate a return to face-to-face cognitive testing where possible now many COVID-19 restrictions have been lifted.

Supporting the findings reported in chapters 3-5, this study again emphasises the influence of acute physical pain on mental health and quality of life and is also linked to a couple of cognitive tests. Therefore, as has been previously suggested, physical pain ought to be closely monitored in athletes regardless of concussion. With evidence that pain leads to elevated depressive symptoms (Walker & Marchant, 2020) and that these elevated depressive symptoms are more prominent at lesser levels of physical pain in female athletes (Walker & McKay, 2022), sports coaches could utilise pain questionnaires with their athletes to inform them of their emotional state. Those with higher levels of self-reported physical pain may be at higher risk of poor mental health and reduced quality of life and therefore any tool that could help inform this ought to be used.

6.8 Conclusions and Future Directions

The present study aimed to investigate the impact of concussion on mental health, cognitive ability, and quality of life over time. This was done by assessing these three areas in those that have previously sustained concussion twice, 6-8 months apart. It was found that concussion appeared to negatively impact cognitive flexibility over time, which would be expected as it is more cognitively demanding due to task switching (Diamond, 2013). However, this may have been due to a speed-accuracy trade-off (Fitts, 1954) as it was also found that participants responded significantly quicker here. The study was also limited by using remote cognitive testing, and perhaps more would have been found with the increased control of face-to-face laboratory testing. Physical pain was once again found to be associated with elevated mental health symptoms and reduced quality of life. Therefore, the present study demonstrates the issues associated with remote cognitive testing and highlights the importance of obtaining physical pain data from sportspeople to predict emotional state and in-turn decide on support.

The past four studies have provided evidence for the negative influence that concussion has on cognitive ability and that physical pain has on mental health and quality of life. With these negative impacts in mind, and the fact that both concussion and physical pain are prevalent in contact sports (Bakhos et al., 2010; Loland et al., 2006; Prokop, 2000), it occurred to us just how safe contact sports were to participate in. When it is commonly understood that physical activity promotes positive mental health (Callow et al., 2020; Saxena et al., 2005), and when contact sports leave sportspeople exposed to high levels of physical pain, the dangers of taking part in contact sports must be understood. This informed Chapter 7 to determine the likelihood of developing depressive symptoms in sportspeople.

Chapter 7: Study 5 – The likelihood of developing depression following sport-related concussion[3]

7.1 Abstract

Risk factors associated with depression in athletes include biological sex, physical pain, and history of sport-related concussion (SRC). Due to the prevalence of pain and SRC altering based on the type of sport athletes compete in, sport-type was also of interest. To our knowledge, there has been no research on how these factors affect the likelihood of depression. In the current study, 144 participants completed a short survey on the above factors and the Center for Epidemiological Studies Depression Scale. Sixty-two of these reported a history of concussion. Logistic regression revealed all the above predictors to be significantly associated with the depression scale. The model suggests that individuals that have previously sustained SRC, experiencing greater physical pain, being female, and participating in contact sports were more likely to present depressive symptoms. Therefore, SRC and physical pain are significantly associated to poor mental health. Our findings regarding sport-type support this with contact sports presenting a greater risk than non-contact sports to poor mental health, likely due to the increased prevalence of SRC and physical pain. Sportspeople should therefore be aware of the present risk in contact sports in their current guise, and effectively communicating these risks to athletes using a simple risk metric is imperative.

Keywords: Sport-Related Concussion, Depression, Physical Pain, Athletes, Biological Sex, Contact Sports

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[3] An adapted version of this chapter has been re-submitted for publication at *PLOS ONE* following reviewer comments. The abstract was also presented as a poster presentation at the *6th International Consensus Conference on Concussion in Sport.*

The introduction section below is a summary of past research that was presented in Chapter 1.

7.2 Introduction

Depression has become an increasing concern across sport. This may be due to prevalence rates ranging from 21% in the USA (Yang et al., 2007) and 43% in the UK (Walker & McKay, 2022) in young adults that visibly exceed the 3.8% of the general population that suffer from the disorder (WHO, 2023). Several risk factors are commonly reported, including biological sex (Walker & McKay, 2022; Wolanin et al., 2016), physical pain (Bodine, 2018; Walker & Marchant, 2020), and sport-related concussion (SRC; Covassin et al., 2012; Rice et al., 2018; Solomon et al., 2016). Despite these links, it is continuously reported that athletes will accept the risk of experiencing physical pain (Liston et al., 2006; Nixon, 1993; Partner et al., 2022) and sustaining SRC (Anderson et al., 2021) when competing. This may be due to the complexity of these issues, in that athletes may report that they understand the risks, but in fact do not. Becker (2009) reported that athletes respond better to simple stimuli from their coaches rather than complex. Therefore, a similar approach should be adopted when attempting to inform athletes of the dangers of SRC and physical pain. Presenting athletes with a simple risk metric, highlighting the risk of developing depression following SRC or when in physical pain may be a more successful technique in encouraging attitude and behaviour change in athletes.

The influence of biological sex on depressive symptoms is difficult to pin-point. Wolanin et al. (2016) found that females are twice as likely to experience depression at some point in their lifetimes than males. Reasons for this include biological differences (Labaka et al., 2018), environmental factors (Cadoret et al., 1985; Rice et al., 2002), stress response (Agoston & Rudolph, 2011; Sowa & Lustman, 1984) and self-esteem (Reynolds et al., 2001).

Despite this males are more likely to die by suicide (Beautrais, 2006; Canetto & Sakinofsky, 1998; Denning et al., 2000; Moore et al., 2018) which questions our understanding of male mental health and coping strategies. This comes in a period where there are many large initiatives promoting male mental health support (O'Reilly et al., 2019; Robertson et al., 2018; Sagar-Ouriaghli et al., 2019) such as *Movember* by the Movember Foundation and the *Best Man Project* by the Campaign Against Living Miserably charity. Therefore, the role of biological sex is one that ought to be continuously investigated to further uncover mental health in men and women.

Physical pain is also often reported as a risk factor for depressive symptoms in sportspeople (Walker et al., 2023; Walker & Marchant, 2020; Walker & McKay, 2022). This is due to the prevalence of increased pain within sport, especially contact sports (Paajanen et al., 2019; Thornton, 2021). However, even in non-contact sports physical pain is likely, with athletes often competing with overuse injuries (Walker & Marchant, 2020) such as repetitive strain (Cutts et al., 2020). Athletes in contact sports regularly continue through the pain barrier (Liston et al., 2006) perhaps due to a culture of being perceived as weak but this could also be explained by social factors such as the potential of losing their position in the team during their absence (Smith & Milliner, 1994). However, it is unclear whether athletes are indeed aware of the link between physical pain and depressive symptoms and the association between depression and reduced sporting performance. Ironically, in a bid to continue their sporting participation by playing through pain, they may inadvertently jeopardise their mental health and performance. Therefore, it is necessary to uncover the likelihood of developing depression following physical pain and communicate this effectively to sportspeople.

Another reason for increased physical pain in athletes could be sustaining SRC. Research into this area was primarily interested in cognitive impairments (Bleiberg et al., 2004; Collie et al., 2006; Guskiewicz et al., 2005), before a focus on mental health derived

(Didehbani et al., 2013; McGraw et al., 2018; Weir et al., 2009). Didehbani et al. (2013) found that affective scores obtained using BDI-II were significantly higher for athletes with a history of concussion compared with matched athletes with no history of concussion (M = 1.59 vs. 0.38). Research like this has promoted examining mental health in those that are likely to sustain SRC, with depression continuously linked (Covassin et al., 2012; Rice et al., 2018; Solomon et al., 2016). As with physical pain, the attitudes of many sportspeople towards sustaining SRC are harmful, and many perceive head injury as a risk that they are willing to take to succeed in their sport (Anderson et al., 2021). However, it is unlikely that these athletes are truly aware of the danger of SRC and the likelihood of developing depression following this type of impact. Therefore, as with physical pain, it is necessary to identify the likelihood of developing depression following SRC and informing sportspeople of the danger that SRC has to their mental health.

Given what we know about the influence of physical pain and SRC on depression, it is plausible to suggest that the same risk is not applicable to all sports. It is reasonable that we may expect a greater chance of sustaining SRC and experiencing elevated levels of physical pain in contact sports such as rugby than in non-contact sports such as tennis. However, it is equally important to understand the likelihood of developing depression in non-contact sports and contact sports and in non-athletes, given that physical pain is still present in all groups and engaging in physical activity has been found to alleviate depressive symptoms (Callow et al., 2020; Dinas et al., 2011; Saxena et al., 2005). It is important to understand the influence of sport-type on depression, as this will corroborate or undermine the influence of SRC and physical pain on this outcome.

Though there are numerous studies indicating that females are more likely to be depressed than males, the disparity in suicide cases suggests continued research into the role of biological sex on depressive symptoms is required. Physical pain and SRC are continuously found to be linked with depression, however, a simple risk metric is required to illustrate how much risk athletes are at if experiencing physical pain and/or have sustained SRC. Communicating this will allow sportspeople the opportunity to make an informed decision as to whether they would like to take the risk of competing. The present study therefore aimed to provide such a metric by exploring the likelihood of developing depression based on biological sex, physical pain scores, SRC history, with sport-type included to corroborate or contradict SRC and pain findings.

7.3 Method

Participants

A convenience sample of 144 participants (Age, *M* = 22.79, *SD* = 5.61) was obtained consisting of 68 males (Age, *M* = 24.41, *SD* = 5.50) and 76 females (Age, *M* = 21.34, *SD* = 5.33). Participants were recruited via the online departmental recruitment system within the university, advertisements on social media platforms LinkedIn and Twitter as well as word of mouth. Men and women over 18 years of age were welcomed to take part in the study. All participants self-reported whether they had sustained SRC and if so, how many. No formal diagnoses were collected in this study. For those that had sustained concussion, a minimum of 28 days must have passed before taking part in this study to avoid exacerbating post-concussion symptoms due to the surveys being displayed on a computer screen. Those that had sustained concussion < 28 days were ineligible to take part until this period of time had elapsed. There were 74 participants that did not take part in any sport at all, 19 that competed in different non-contact sports (athletics, netball, squash, touch rugby, cricket, baseball, weightlifting, handball, cycling, equestrian, badminton, and dance), and 51 that took part in contact sports (rugby union/league, football, skiing, boxing, and taekwondo). A more in-depth break down is presented in Appendix A. Sixty-two participants reported having sustained SRC in the past four years (months since last concussion – *Range*, 1-48, *M* = 18.87, *SD* = 14.01), totalling 223 SRC's between them (*Range*, 1-12, *M* = 3.60, *SD* = 2.80). Appendix R presents the number of SRC's by sport-type and non-sport. These three factors were used for data analysis alongside scores of physical pain.

Sample size calculations

Sample size calculations were calculated post-hoc using G*Power 3.1.9.7 software. Logistic regression using 144 participants provided excellent power (β =0.97) to detect an OR of 3 and effect size of $f^2 = 0.5$ (large effect size) at $\alpha = 0.05$. A large effect size was used in calculations due to the time difference between certain dependent variables (SRC history being 28+ days ago compared with physical pain in the past week).

Measures

Refer to Chapter 2 for below measures:

- General Information Questionnaire (GIQ)
- Numeric Rating Scale (NRS-11; Downie et al., 1978)
- Center for Epidemiological Studies (CESD; Radloff, 1977)

Data Analysis

Binary logistic regression investigated the odds ratios of the four independent variables (sex, sport-type, physical pain and SRC history) on the likelihood of depressed categorisation (scoring ≥16 on CESD). It was predicted that being male, engaging in contact sport, in physical pain and having sustained SRC would increase the chances of depressed categorisation.

Refer to Chapter 2 for information regarding procedure and ethics.

7.4 Results

Assumptions

There are some assumptions that are required for logistic regression to provide a valid result (Field, 2013). Firstly, the dependent variable ought to be binary. In this study, depressed categorisation (depressed/non-depressed) was the dependent variable, and therefore this serves as a binary dependent variable and satisfies this assumption. We have justified our sample in sample size calculations and therefore this assumption is also satisfied. Finally, logistic regression requires little to no multicollinearity among independent variables. Correlation analysis displayed in Table 1 shows independent variables are not highly correlated with each other. This is due to the general rule of thumb that correlation coefficients between two variables are less than 0.9 (Senaviratna & Cooray, 2019), of which all are in our analysis.

Table 1. Correlations of independent variables

	Sex	Physical Pain	SRC History	Sport-type
Sex	-	-	-	-
Physical Pain	.018	-	-	-
SRC History	-.554*	.128	-	-
Sport-type	.483*	-.053	-.747*	-

*- $p < .01$

Descriptive Statistics

Seventy-six (52.8%) participants scored ≥16 and were therefore included in the depressed group for logistic regression whereas the remaining 68 (47.2%) participants that scored < 16 on the CESD were included as the non-depressed group. It is also important to note that 47 (92%) of those that took part in contact sports had previously sustained concussion compared with 7 (36%) of those that took part in non-contact sports and 8 (11%) of participants that took part in no sport at all. Scores of physical pain and depression by sport type are presented in Table 2.

Table 2. Descriptive statistics depicting scores of physical pain and depression by sport type								
	Physical Pain				Depression			
	N	Range	*M*	*SD*	*N*	Range	*M*	*SD*
No sport	74	0-8	2.60	2.03	74	2-54	21.97	12.41
Non-contact sport	19	0-6	2.68	1.97	19	5-44	17.26	12.12
Contact sport	51	0-8	2.84	2.10	51	1-52	15.02	11.61

Logistic regression

Binary logistic regression was performed to assess the impact of a set of predictor variables on the odds that respondents would report depressive symptoms. Meaningful depressive symptoms were operationalised as scoring ≥16 on the CESD (Husaini et al., 1980). The model contained 4 independent variables (sex, physical pain, SRC history and sport-type). Sport-type was either non-sport for non-athletes or contact or non-contact sports for athletes. The full model containing all predictors was statistically significant χ^2 (5, N = 144) = 41.61, p = .000, indicating that the model was able to distinguish between respondents whose CESD scores were below or above the cut-off score of 16. The model correctly classified 70.8% of cases. As shown in Table 3, all four predictors made a unique statistically significant contribution to the model. The strongest predictor of depressed categorisation was participating in contact sport with an odds ratio of 71.43, indicating that the likelihood of being depressed is 71 times more likely in those that compete in contact sports compared to not taking part in sport. This is supported by finding those with history of SRC were almost 57 times more likely to be depressed. Interestingly, even those that took part in non-contact sports were 4.4 times more likely to be depressed. Respondents were also 1.4 times more likely to be depressed for every score of physical pain they reported, and females were 2.9 times more likely to be depressed than males.

Table 3. Logistic regression predicting the likelihood of reporting meaningful depressive symptoms

	B	*SE*	Wald	*df*	*p*	Odds Ratio	95% CI for Odds Ratio Lower	Upper
Sex	1.06	.49	4.69	1	**.030***	2.89	1.11	7.57
Physical Pain	.32	.11	9.22	1	**.002****	1.38	1.12	1.69
SRC history	4.04	1.23	10.84	1	**.001****	56.98	5.14	632.17
Non-Contact Sport	-1.48	.72	4.18	1	**.041***	4.37	1.06	17.86
Contact Sport	-4.28	1.24	11.92	1	**.001****	71.43	6.37	1000.00
Constant	-1.25	.55	5.15	1	**.023***	.29	-	-

*- Significant at $p < .05$ **- Significant at $p < .01$

7.5 Discussion

This study aimed to provide a simple risk metric for sportspeople of the likelihood of developing depression based on biological sex, physical pain and SRC history, with sport-type also examined. It was found that belonging in each of the following will increase the chances of depression: i.e., being female, experiencing physical pain and having sustained SRC. It was also found that taking part in contact sports was a greater risk factor than taking part in non-contact sports, likely due to the higher prevalence of SRC and physical pain in the former. With these findings, sportspeople can make a more informed decision as to whether they are willing to accept the risks of sustaining SRC and experiencing physical pain given the evidence provided here.

Females have often reported higher depression rates than males (Walker & McKay, 2022; Wolanin et al., 2016) with similar found here. Analysis revealed that females are almost three times more likely to be depressed than males. This is likely due to biological differences (Labaka et al., 2018), environmental factors (Cadoret et al., 1985; Rice et al., 2002), stress response (Agoston & Rudolph, 2011; Sowa & Lustman, 1984) and self-esteem (Reynolds et al., 2001) that have all been found to explain increased prevalence of depression in women. Underreporting from males may also contribute to this finding as they opt to conceal emotional vulnerability due to stigma that this may be perceived as weakness, especially in athletes where positive self-image is a primary focus (Soulliard et al., 2019).

This comes in a time where male suicide cases exceed female cases (Beautrais, 2006; Canetto & Sakinofsky, 1998; Denning et al., 2000; Moore et al., 2018), and therefore research of this ilk may not truly capture the role that biological sex has on mental health such as depression. That said, females have previously reported higher depressive symptoms at lower levels of physical pain than males (Walker & McKay, 2022) and therefore this study complements this evidence that physical pain may influence females' mental health before that of males.

There is a growing body of research indicating a link between physical pain and depression (Ishak et al., 2018; Walker & Marchant, 2020), justifying developing a simple risk metric for this factor. In the present study, participants were 1.38 times more likely to be depressed for every score of physical pain reported using the NRS-11. As this tool is an 11-point Likert scale (0-10), this finding should not be ignored. At face value, scoring 1 or 2 does not appear a substantial difference, however, with the information presented here we reveal this could be an extensive indicator of poorer mental health and depression. This is particularly important given what we already know from Walker & McKay (2022) regarding female athletes experiencing depression at lower levels of physical pain. Therefore the findings of the present study support this and highlight how we may predict mental health concerns at lower levels of physical pain in female athletes and coaches could tailor their support accordingly using this information.

This study has established that females are nearly three times more likely to develop depression than males in this sample, and participants 1.38 times more likely to develop depression for every score of physical pain on the NRS-11. However, the most pertinent finding is that those that have sustained SRC are almost 57 times more likely to be depressed than those that have avoided SRC. Not only does this support previous research that highlights that SRC can lead to emotional disturbances such as depression (Covassin et al., 2012; Rice et al., 2018; Solomon et al., 2016), but provides a simple risk metric that can be communicated to sportspeople. Social factors could explain this finding such as time lost competing in sport (Kontos & Collins, 2018; Putukian, 2016), not being able to compete to the standard they could prior to SRC (Smith & Milliner, 1994) and changes in cognition that affect daily functioning (De Beaumont et al., 2012). Whichever the case, what is clear is avoiding sustaining SRC significantly protects against depression and this study provides a simple risk metric to aid an informed decision making process from sportspeople.

The risk of SRC and physical pain is profoundly higher in contact sports, due to the nature of the games (Koh et al., 2003; Thornton et al., 2017; Tommasone et al., 2006). With it well known that physical activity acts as a protective buffer against poor mental health (Callow et al., 2020; Saxena et al., 2005), it is currently unclear whether engaging in contact sports is a risk worth taking. In this study, we found that those that take part in contact sports are over 71 times more likely to experience depression compared to those that take part in no sport. This finding is likely due to the increased chance of sustaining SRC and experiencing physical pain, which we have highlighted above to be great predictors of depression. Therefore, as we understand physical activity, including contact sports are beneficial to mental health (Callow et al., 2020; Saxena et al., 2005), it is important to ensure athletes are aware of the risks of taking part in contact sports to their mental health, due to the increased prevalence of SRC and physical pain, despite emotional benefits of physical activity (Callow et al., 2020; Saxena et al., 2005). This finding should not be interpreted as contact sports being negative for mental health, rather that it corroborates what we expect to be a negative effect from SRC and physical pain.

Furthermore, those that took part in non-contact sports were over four times more likely to show meaningful depressive symptoms than those that engaged in no sport at all. As there is abundant evidence that suggests physical activity is positive for mental health (Callow et al., 2020; Saxena et al., 2005), we cannot conclude that taking part in no sport at all is better for mental health. Instead, this finding is likely due to misclassifications between groups. Of the 74 participants in the ’no sport’ group 8 (11%) had previously sustained SRC. This figure is compared to 7 (36%) of the 19 participants in the ‘non-contact sports’ group, and therefore the higher prevalence of SRC in non-contact sports could explain the increased likelihood of developing depression in this group compared with the ‘no sports’ group. This further strengthens our findings regarding the role of SRC. There are also touch rugby players, who are classified as non-contact sport athletes in this study. These players were likely to be full contact rugby players previously that have removed themselves, perhaps due to SRC and its effects, and therefore this could also exaggerate the negative influence of non-contact sports on mental health but is still captured in SRC findings.

It should also be noted that physical pain is still common within non-contact sports which could explain the increased risk to mental health in the present study. Repetitive strain injuries often occur in non-contact sports and the stressors of competition are still present. Table 1 highlights that physical pain is worse in contact sports, and least in the ‘no sports’ group. Therefore, physical pain could explain why those in non-contact sports were more likely to be depressed than those that do not take part in sport in the present study. However, this difference is marginal and should be inferred with caution rather than deterring sportspeople from non-contact sports. Therefore, athletes should consider carefully whether exposing themselves to SRC and physical pain in contact sports is a risk worth taking. This decision can be made easier by providing them with the simple risk metrics we have produced in this study.

7.6 Limitations

There is a risk of self-selection bias due to the voluntary nature of our recruitment and the way the study was advertised, though this is common in the literature (Walker & McKay, 2022). Another limitation of the present study is regarding sport-type SRC's. What constitutes contact sports and non-contact sports is debatable but there are not many that would dispute what category a certain sport belongs to. However, there are instances whereby even when the sport is defined as non-contact due to the laws of the game, SRC can still occur. For example, cycling would be considered a non-contact sport for many but if falling during a sprint the chance of sustaining SRC increases. In the present study, touch rugby is defined as a non-contact sport but there are a lot of SRC's that have occurred. This is likely a reflection of participants only reporting their predominant sport at the time of participating, and therefore it is not possible to truly determine where SRC was sustained. In future, studies should ask participants to not only report their predominant sport at time of taking part, but also what sports they were taking part in when SRC occurred, as this could be different, or there could be SRC's across multiple sports. Including this would amend for potential misclassifications that may be present in this study.

Additionally, regardless of which sport participants predominantly took part in, the present study utilised a self-report technique regarding SRC history. Without diagnoses, it is possible that the total number of SRCs are inflated in this study, as can be viewed in Appendix B, and therefore the reader should take this into consideration when inferring the results. However, concussion is a lived experience and therefore we would argue that if an athlete is reporting having sustained concussion then it is likely because they have experienced concussion symptoms. As we know that not all concussions present symptoms, it could be that there is in-fact an underreporting of total number of SRCs. Therefore, although there is less control here than if we had sought clinical diagnoses of concussion, there is still value in trusting the athletes lived experience of what they deem concussion to be.

7.7 Practical Implications

The main purpose of this study was to provide simple risk metrics for sportspeople, to aid in their decision making process of competing in their sports. From the present study we can aid athletes with this decision by informing them that they are 1.38 times more likely to suffer from depression for every score of physical pain they experience (0-10), and that they are 57 times more likely to be depressed if they sustain SRC. This simple risk metric will help sportspeople make an informed decision on whether they want to take part in their sport, with them aware of which type of sports are prone to these factors. We also provide evidence that females are nearly three times more likely to be depressed than males, and therefore the impact of SRC and physical pain may be more pronounced in females. This has been previously reported with physical pain (Walker & McKay, 2022) but not with SRC.

7.8 Conclusions and Future Directions

The present study provides simple risk metrics for the likelihood of developing depression following SRC or when in physical pain. To our knowledge, we are the first to calculate these and therefore the present findings add value to the literature. It is vital to continue researching the role of biological sex on mental health disorders, such as depression, as females are often found to be at greater risk, while it appears that males conceal this personal information. Continuing to examine this area better allows us to support and protect vulnerable sportspeople. Additionally, we have found that SRC and physical pain provide a significant risk to mental health which is corroborated by those that take part in contact sports, where these factors are prevalent, presenting a greater risk of depression. Interestingly, those that take part in no sport at all were less likely to be depressed than those that take part in non-contact sports. This is perhaps due to painful repetitive strain injuries participants in the ‘non sport’ group having previously sustained an SRC and withdrawing from that sport due to its effects. Therefore, sportspeople should not be deterred from engaging in physical activity but should be aware of the simple risk metrics developed in this study regarding SRC and physical pain to make an informed decision on their participation.

The past five studies show the negative influence that concussion has on mental health, cognitive ability, and quality of life. While physical pain does play a significant role on mental health and quality of life, and this may be lost in a lot of current concussion literature assessing these outcomes, Chapter 5 suggests cognitive impairments in post-concussed samples. Additionally, concussion history does increase the likelihood of developing depressive symptoms as depicted in Chapter 7. Therefore, the question arises as to why many still engage in contact sports, especially amateurs. It is possible that sportspeople's attitudes and knowledge towards concussion may explain the reason for continually risking the chances of sustaining concussion and the potential adverse effects. Therefore, the next study looked at investigating the attitudes and knowledge in amateur rugby players to uncover the mechanisms of this risk-taking behaviour.

Additionally, as the role of physical pain is so prevalent in the past five studies, it seems naïve that research should continue to use the simplistic Likert scale that is the NRS-11. One of the limitations of this scale is that it only assesses acute pain, at the time of participating, and while this does have its benefits particularly to mental health and quality of life scores, it is limited to how pain across time may influence these factors and cognition. As well as that, it may be simplistic in that there are many areas of physical pain, and the NRS-11 only captures total physical pain. For example, women at certain points in their menstrual cycle may experience higher levels of physical pain than women at other points and men who do not menstruate. With the NRS-11 this factor is lost, and it is assumed that pain is sustained through competing in sport. Therefore, Chapter 9 proposes a new physical pain scale that attempts to measure physical pain across time points to see if there are differences between these two time-points, as well as recording different types of pain. It is hoped that this new pain scale can be used within sports teams to aid coaches in predicting poor mental health and reduced quality of life in athletes as suggested in Chapters 3-7.

Chapter 8: Study 6 - Targeting competency of non-players to improve concussion attitudes in amateur rugby

8.1 Abstract

Concussion is prevalent in British amateur rugby and there is currently contradicting evidence of the attitudes and knowledge of concussion in rugby players. While much of the literature aims to investigate this area using the Rosenbaum Concussion Knowledge and Attitudes Survey, the reliability of the Concussion Attitude Index is questionable. As concussion is a lived experience within sport, this study utilised qualitative interviews using thematic analysis to assess data obtained from nine amateur rugby players that had all sustained over three concussions. It was revealed that *poor duty of care* from those around the athlete with suspected concussion was prevalent, and that this poor duty of care promotes athletes to adopt poor attitudes and knowledge of concussion. It was also discovered that *incompetence* may help explain this poor duty of care that is offered to rugby players by non-players. *Poor duty of care* and *incompetence* encourage continued participation from the player with suspected concussion. Therefore, the competency of non-players in attendance at amateur rugby matches is paramount in tackling the poor attitudes and knowledge base that we see from players in the amateur rugby game.

Keywords: Concussion, Amateur Rugby, Attitudes, Knowledge, Duty Of Care, Competency

The introduction section below is a summary of past research that was presented in Chapter 1.

8.2 Introduction

The dangers of concussion are becoming better-known within academia, and therefore it is necessary for this wealth of knowledge to be transferred to and applied in real life (i.e. sport activities). Rugby has been found to have the highest prevalence of concussions both in match play and training (Prien et al., 2018) when compared with other contact sports such as football, ice hockey, and American football. This is measured in Athletic Exposures (AE) which is defined as one athlete participating in one game or training session with the incidence rate shown as *x* per 1,000 AE. Prien et al. (2018) found men’s rugby to have an incidence rate of 3.00/1000 AE in matches and 0.37/1000 AE in training, with men’s football displaying the lowest incidence rate (1.07/1000 AE in matches and 0.08/1000 AE in training). Albeit descriptive, it indicates that rugby players are at increased risk of sustaining sport-related concussion and the negative consequences associated such as poorer mental health (Gornall et al., 2021; Ledoux et al., 2022), impaired cognition (McGowan et al., 2019; Moore et al., 2014), and reduced quality of life (Doroszkiewicz et al., 2021).

Register-Mihalik et al. (2013) examined the knowledge, attitudes, and concussion-reporting behaviour of high school athletes. It was found that only 40% of concussions were disclosed after a possible concussive event. Interestingly increased athlete knowledge of concussion was associated with increased reporting of concussion, signifying the importance of this knowledge base. Likewise, safer concussion attitude was associated with lesser continued participation with suspected concussion. This is supported by Beran and Scafide (2022) whereby their systematic review of 22 studies reported that 6 of these found concussion education had a positive impact on knowledge and reporting behaviours.

Therefore, knowledge of and attitudes towards concussion are key for management and initial prevention. However, neither Register-Mihalik et al. (2013) nor Beran and Scafide (2022) included rugby players in their studies, and therefore, the knowledge and attitudes of a popular contact sport where concussion is likely are absent.

Contradicting evidence exists regarding whether rugby players possess safe concussion attitudes (Kraak et al., 2019) or not (van Vuuren et al., 2020) and Viljoen et al. (2017) also found poor knowledge in amateur rugby players that may lead to poor attitudes and behaviour regarding concussion. These studies however, utilised the using the Rosenbaum Concussion Knowledge and Attitudes Survey (RoCKAS) when investigating rugby players knowledge, attitudes, and reporting intentions. While RoCKAS seems to be a widely used tool when assessing concussed athletes, the validity of the Concussion Attitude Index (CAI), the aspect of the survey measuring attitudes toward concussion, is questionable with indications of poor reliability (Chapman et al., 2018). Additionally, AlHashmi and Matthews (2021) argue that the use of RoCKAS limits participants' responses as they are restricted to predetermined questions and answers. For example, one item of the CAI asks players their level of agreement on whether they would continue playing while displaying concussion symptoms. With it already heavily reported in the literature that rugby players are likely to play on with suspected concussion (Liston et al., 2018; Malcolm, 2009), it is necessary to identify the reasons for this so to combat them. As well as this, with contradicting evidence of whether rugby players hold unsafe attitudes towards concussion (Kraak et al., 2019; van Vuuren et al., 2020; Viljoen et al., 2017), the reasons for this ought to be explored. Qualitative approaches such as interviews may be more suitable as they can gather deeper, more personal and lived experiences from athletes. Thematic analysis (TA; Braun & Clarke, 2019) is popular when analysing interviews as it provides insight into identifying and organised patterns of meaning (Braun & Clarke, 2019). Therefore, interviews using TA analysis may be more appropriate than quantitative methods such as RoCKAS to effectively assess amateur rugby players attitudes and knowledge of concussion.

Many amateur rugby players continue to play with suspected concussion (Liston et al., 2018), which Liston et al. (2018) describe as players being “head strong”. Players often downplay, deny, or conceal their concussion symptoms and play on, due to this attitude of presenting a high level of commitment to your teammates and to the sport. That is, there is a subculture whereby amateur rugby players despite their amateur status, often prioritise sporting values rather than health-related ones, rewarding serious risk taking (Liston et al., 2018). As continuing participation with a suspected concussion has been reported to exacerbate symptomology (Howell et al., 2020) and therefore the negative consequences associated, the successful removal of these players is vital.

In summary, there is currently contradictory evidence of attitudes towards concussion (Kraak et al., 2019; van Vuuren et al., 2020; Viljoen et al., 2017), with RoCKAS the most widely used tool to examine this area. Due to reliability issues of this measure, as well as its restrictive nature of investigating lived experience, qualitative interviews may provide a deeper insight into the attitudes and knowledge base that rugby players have that expose them to a higher rate of concussion. By understanding the attitudes and knowledge base of concussion in rugby players, we may be better placed to reduce negative attitudes such as continued participation (Howell et al., 2020) and non-adherence to return-to-play protocols (van Vuuren et al., 2020).

8.3 Method

Research Paradigm

The researchers adopted an interpretivist ontological view when constructing the research question. That is that the world is complex and dynamic, and people experience reality in different ways (Aliyu et al., 2015). As concussion is becoming more known as a personal experience (Anderson et al., 2006), it was believed that an interpretivist view was appropriate, to uncover the reality of the participants that have undergone this head trauma in sport. It is important to understand the way in which athletes reach these attitudes towards concussion, rather than simply understanding what attitudes they possess (Aliyu et al., 2015).

Situating the authors

The authors have not sustained concussion first-hand but take a keen interest in sport which has made the increasing attention on head injuries, particularly in contact sports, unavoidable. When leading healthy, balanced, active lifestyles, the authors are motivated for others to adopt a similar outlook. We have good knowledge of concussion having researched this area, as well as contextualising this in a sporting setting. Biases may exist regarding predicted reasons for the attitudes and knowledge base of concussion in amateur rugby players, however interview scripts were designed to alleviate any potential biases. That said, as we took an ontological view, with the belief that people experience reality in different ways, and that it is necessary to explore the way in which athletes reach this knowledge base and attitudes, a semi-structured nature was implemented. This allowed us to ask follow-up questions in the moment, to uncover this process.

Participants

Nine amateur rugby players (7 Male, 2 Female) that had all sustained multiple concussions participated in the present study (Age, M = 24.67, SD = 5.10). Amateur status was defined by the athletes themselves, and therefore is operationalised as self-identification being an amateur athlete. Further information regarding concussion profiling is presented in Table 1. Participants were recruited via advertisements on social media platforms such as Twitter and

LinkedIn as well as word of mouth. All participants took part in semi-structured interviews designed to investigate their attitudes and knowledge towards concussion in rugby.

Table 1. Concussion Profiles

	N
Total Participants	9
Sustained over three concussions	9/9 (*Range* = 3-20, *M* = 8.13, *SD* = 5.59)
Sustained over five concussions	5/9 (*Range* = 3-20, *M* = 8.13, *SD* = 5.59)
Sustained first concussion before 18 years of age	5/9
Continued participation with concussion symptoms	9/9
Witnessed others continue with concussion symptoms	9/9

Refer to Chapter 2 for information regarding procedure, data analysis and ethics.

8.4 Interview Findings and Discussion

Through a process of thematic analysis of the interview transcripts, themes of a poor duty of care and incompetence were developed. Participants recalled examples where poor duty of care was evident from various sources in their playing careers. Many suggested that their coaches possess unsafe attitudes towards concussion, perhaps inherited from the coaching style they received in their own playing career (Lyle, 2005) and contradicting the findings from Salmon et al. (2021). It is unlikely that these coaches are actively attempting to cause harm to their players, instead more likely trying to “toughen them up” and to become “head strong” (Liston et al., 2018). However, research on group dynamics and behaviour suggests that individuals will not only observe the social rules within the group but also outside of it to secure their place in the group (Bilgin, 2013) and therefore this poor practice encourages players to adopt the same attitudes. Participant 5 stated “sometimes…your manager…will be a bit understanding but…if you’re a forward (the) forwards coach will be…like you're getting back on…and a lot of your teammates will try and like hype you up…you're alright…and I'm probably guilty of that. I've probably done that as well.” This passage highlights worrying attitudes and duty of care from coaches that are then exhibited in players/teammates themselves. This pressure from teammates and coaches is increasing the number of amateur rugby players that are continuing with potential concussion and therefore placing themselves and others at exceptional risk. Therefore, combatting attitudes of coaches may help in improving their duty of care, which in-turn may improve the attitudes towards concussion in players/teammates and reduce pressure from coaches and teammates to continue with suspected concussion.

More surprisingly, it was revealed that club doctors and match officials also fail in their duty of care towards players. It is already concerning that coaches possess poor concussion attitudes that leads to a poor duty of care of their players, and that these behaviours are also shown to transmit to their players. However, it is unexpected that similar are also found with club doctors and match officials. Our interviews highlighted an issue within amateur rugby whereby club doctors may not always be qualified with participant 4 referring to "token first aiders" that will administer "some kind of assessment". This was reiterated by participant 1 who recollected a time where "somebody shoved some bog roll in my face and said…we'll sort you out and get you back on". This does not appear to be the practice of healthcare professionals which would lead us to conclude and that it is not. Therein lies another issue in combatting concussion in amateur rugby. If you have an unqualified carer, then you will receive unqualified care, and ensuring that all amateur rugby has an impartial qualified healthcare professional present is paramount for the protection of the players. This is an example that contributed to the development of the theme *incompetence.*

Likewise, it appears that the expertise of officiating could be called into question in the amateur rugby game. Just as we have illustrated with club doctors, there is evidence of referees also not meeting what is required of them regarding their duty of care to the players.

Participant 1 recalled “the referee had stopped the game because we were playing with fewer numbers anyway and said, well, is he coming back on because it was just a nosebleed”. Once again, these are unlikely words of a trained referee, or at least one that does not understand concussion protocol and the signs and symptoms of head injury. As there is currently a referee shortage across sports (Swanson, 2018), it might be the case that not all referees in the amateur game are qualified and knowledgeable about concussion symptoms and the use of protocols regarding protecting the players. Here we now have an athlete that has sustained a suspected concussion and their coach and teammates are questioning their commitment and ability to perform. The club doctor has failed to protect them too perhaps due to not being qualified themselves, and now the referee has paused the match to ask whether they are returning to play. There are four different facets that have failed to protect this individual: coach, teammates, club doctor, referee. Four, have failed to protect the player when in a healthy conscious state of mind, and instead are not only asking a potentially concussed individual if they want to continue playing, but placing pressure on this individual to do so. This is an abhorrent lack of care and one that stems from poor knowledge of and attitudes or incompetence of protecting players from concussion in rugby.

In fairness to referees, there are also instances where concussion protocol is followed, but withdrawing athletes from the field of play is made more difficult due to player attempts to deceive. This has been reported in contact and non-contact sports with Whatman et al. (2018) finding 87% of their sample reported concealing an injury to continue playing. The same was found here where participant 3 referred to “the ones you can hide (where) the ref doesn’t see it, so you carry on” and participant 8 spoke of teammates claiming, “it wasn’t my head I just hurt my shoulder.” This is something made more difficult due to squad numbers in the amateur rugby game. Many participants in this study referred to it being common to have low squad numbers, and therefore withdrawing themselves in any circumstance, not just with concussion, is viewed negatively as it would place the team at a numerical disadvantage. Participant 4 stated that “it doesn't help when we play…sometimes you turn up with 15/16 players. So if somebody has an injury, it's almost like right, nobody else can get injured. So that hesitancy of going off as well.” This is supported by participant 3 saying that they “used to play for a team that didn't have a very large subs bench. So, you kind of have to carry on, otherwise, you were playing with lower numbers. So, we did quite often get a bit of water splashed on our faces, and off you go.” Therefore, player numbers appears to be a contributing factor to continued participation with a suspected concussion. Ignoring this, may lead to a less required outcome even when addressing attitude change in coaches and improving the requirements of expertise in club doctors and referees.

The main issues identified from the transcripts is a poor duty of care from coaches, teammates, club doctors and referees and an incompetence from these non-players to protect their players from concussion. Attempts ought to be made to educate coaches on the dangers of concussion to promote attitude change, leading to a greater duty of care and in-turn improving the competence of protecting players. Provisions also ought to be established regarding the expertise of healthcare officials and referees, again to improve the level of care that injured players receive.

8.5 Limitations

Although other studies that have investigated this area have obtained much larger samples (AlHashmi & Matthews, 2021; Liston et al., 2018) qualitative research is unconcerned with sample sizes. Instead, the depth and richness of the rugby player’s experiences of concussion was of interest here. This was successfully explored, as all nine participants had sustained over three concussions with one having sustained over twenty. All admitted to continuing playing with concussion symptoms as well as seeing others do the same. Over half had sustained concussion before adulthood. Therefore, the sample are well-qualified to share their experiences of concussion, and the findings here are valuable.

Our recruitment strategy should also be noted. We recruited participants using advertisements across the university as well as with social media posts, and therefore the data may suffer from self-selection bias. That is that the findings that we have obtained may reflect individuals that have had the worst experiences post-concussion. Many sustain concussion and show no symptoms (Collie et al., 2006), and therefore these athletes may have less motivation to take part in a study attempting to understand concussion in amateur rugby like the present study. By contrast, those that have dealt with more negative experiences post-concussion are perhaps more likely to take part in an attempt to help others and that could explain the current findings. However, we would argue that even if this is the case, there is value in examining the worst experiences of concussion satisfying the ontological view of the researchers. These nine amateur rugby players highlight the negative consequences of head injury in their sport and can promote positive concussion attitudes and knowledge.

Additionally, participants all competed in amateur rugby in the UK, limiting these findings to just this demographic of players. This is considerably different to the way concussion in the amateur rugby game is reported and managed in other popular rugby playing nations such as New Zealand and South Africa. Most notably, a “Blue Card” system has been introduced in these nations, whereby a referee is empowered to issue such card to any player they suspect of being concussed and removing them from the game (Sullivan et al., 2017). As this is not present in the UK, it could be argued that this places increased pressure on continuing participation rather than having this decision taken away from them due to being shown a Blue Card. Likewise, Sullivan et al. (2017) report that referees feel more comfortable and empowered to remove a player with suspected concussion due to the blue card, therefore improving duty of care. Therefore, the present study can only be generalised to amateur rugby in the UK given different provisions already in place in other countries.

8.6 Practical Implications

The size of rugby teams has been uncovered as an issue in the present study. With starting line-ups of rugby league and rugby union teams thirteen and fifteen respectively, the sport relies on many people to be committed to the club. Given that there is no financial benefit, by definition, in amateur sport, it is understandable that this commitment may be jeopardised sometimes, and other life obligations take priority. If this leaves the team with few, or even no substitutes then this increases the pressure on players to continue with suspected concussion, and on coaches, club doctors and officials to ignore concussion symptoms. This is endangering the player to further injury, that can be fatal (Tator et al., 2019). In response to this, it could be that teams ought to have a certain number of players for the game to begin. Perhaps five substitutes. If this requirement is not met, the match should either be postponed, or a rugby sevens match could take place if agreed by both sides.

Additionally, improved education of concussion ought to be incorporated into the amateur game. The variance in the attitudes and knowledge base is worrying. As any positive attitudes and good knowledge base appears to be due to players having sustained concussion, this is further cause for concern. Improved education for young amateur players as well as their coaches and officials will reduce continued participation with suspected concussion. This in-turn will prevent players exacerbating concussion symptoms and its negative consequences such as poor mental health (Gornall et al., 2021; Ledoux et al., 2022), impaired cognition (Gonzalez et al., 2021), and reduced quality of life (Doroszkiewicz et al., 2021).

8.7 Conclusion and Future Directions

This study provides a deeper understanding of the shared attitudes and knowledge base of amateur rugby players towards concussion. A poor duty of care coupled with incompetence from non-players in protecting those with suspected concussion promotes poor attitudes and knowledge of concussion that we see in amateur rugby players. This in-turn leads to continued participation with suspected concussion which is very dangerous (Howell et al., 2020). Improving education of non-players in amateur sport could improve duty of care and competence towards players and improve attitudes and knowledge within amateur rugby and reduce this continued participation with suspected concussion. Coupled with a change of policy regarding minimum number of substitutes, players will be more likely to withdraw themselves, protecting themselves from the negative consequences of concussion.

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Chapter 9: Study 7 – The Localised Pain Scale: Developing a new pain scale

9.1 Abstract

Investigating pain is difficult due to individual differences in their perception of pain and this can influence the use pain questionnaires. Currently, the Numeric Rating Scale-11 (NRS-11) and Visual Analog Scale (VAS) are frequently used, however, they only obtain one measure of "overall pain". We propose the Localised Pain Scale (LPS) that attempts to gather data on multiple areas of physical pain across two time-points (Y-1; right now, Y2; in the past week). One-hundred-and-eighty-eight respondents completed the LPS, NRS-11, and VAS and we found that scores of "overall pain" were visibly lower in LPS(Y-1) and LPS(Y-2) compared with NRS-11 and VAS. This could indicate that participants are thinking more deeply about their pain due to the various items that allow a more accurate report which is reflected in lower standard deviations. We found acceptable internal consistency scores and inter-item correlations as well as females reporting higher pain scores on 6 of the 16 items in the LPS. As there were no differences found between sexes using the NRS-11 and VAS, we gather more meaningful data using the LPS, and therefore this ought to be used ahead of the NRS-11 and VAS in future.

Keywords: Physical Pain, Localised Pain Scale, NRS-11, VAS

The introduction section below is a summary of past research that was presented in Chapter 1.

9.2 Introduction

Researchers have long been interested in studying physical pain with the intention of improving the daily lives of those experiencing it. There have been important advances in assessing conditions where chronic physical pain is due to physical disorders such as arthritis (Neugebauer et al., 2007; Pincus & Sokka, 2003), fibromyalgia (Hackshaw, 2020) and multiple sclerosis (Hirsh et al., 2009; Solaro et al., 2004). However, the methods of investigating everyday physical pain can be scrutinised. Currently, the most widely used physical pain questionnaires for everyday pain are the Numeric Rating Scale-11 (NRS-11; Downie et al., 1978) and Visual Analogue Scale (VAS), the latter first used in psychology by Freyd (1923). While these tools aim to provide a cross-sectional measure of acute physical pain experienced, they could be regarded as too simplistic (Safikhani et al., 2018). As those living with physical pain are likely to exhibit poorer mental health (Ishak et al., 2018; Walker & Marchant, 2020; Walker & McKay, 2022), developing a more nuanced scale of physical pain that measures different areas of pain as well as across different time points may be beneficial.

The NRS-11 has been used extensively to assess acute physical pain (Sigurdsson et al., 2021; Walker & Marchant, 2020; Walker & McKay, 2022). For example, Walker and Marchant (2020) used the NRS-11 alongside the Center for Epidemiological Studies Depression questionnaire (CESD; Radloff, 1977) to examine pain and depressive symptoms respectively in 111 student athletes. Using the recommended cut-off score of ≥16 indicative of showing meaningful depressive symptoms (Husaini et al., 1980), it was found that those scoring in this category displayed significantly higher pain scores than those that scored below this mark on the CESD. Walker and McKay (2022) built on this by demonstrating that both biological sex and physical pain were associated with elevated depressive symptoms in 130 student athletes. Therefore, the NRS-11 has been helpful in demonstrating an association between increased physical pain and elevated depressive symptoms.

Moreover, the VAS is also often used (Cozzolino et al., 2019; Danoff et al., 2018; Lau et al., 2013) and now there are attempts to validate a digital version building on the traditional paper-based version (Delgado et al., 2018; Escalona-Marfil et al., 2020). Lau et al. (2013) examined whether VAS and pressure pain threshold (PPT) would provide the same results when assessing delayed onset of muscle soreness (DOMS). DOMS is a common musculoskeletal consequence of physical activity and sporting participation, and therefore sportspeople are likely to experience this level of pain. For this reason, Lau et al. (2013) used an athlete sample. It was found that VAS and PPT provide different information about DOMS, indicating that the two tools represent different aspects of pain. Similarly, VAS and NRS-11 are often compared with one another (Alfonsin et al., 2019; Chiarotto et al., 2019; Shafshak & Elnemr, 2021) with Hartrick et al. (2003) finding that participants scored significantly higher on NRS-11 than on VAS and Chiarotto et al. (2019) concluding that neither are superior in measuring lower back pain.

Using this information, the disparity between these pain questionnaires could be due to trying to capture a whole picture of pain using a simplistic solitary tool. We pose participants trying to report their physical pain in the past week is difficult on an 11-point Likert scale like the NRS-11. For example, someone that may be in no pain at all but had a severe headache six days ago may feel obligated to report some level of pain, but this may be understated due to the trade-off due to a whole picture approach. This individual may report a one or a two on the NRS-11 when their actual pain may have been an eight or nine at the time. Therefore, separating the same scale into two sections; ‘right now’ and ‘in the past week' may reveal more accurate data of self-reported physical pain, as well as localising the areas of pain rather than a global measure.

We propose the Localised Pain Scale (LPS) as a new measure of self-reported physical pain. Given the limitations of the NRS-11 and VAS measuring pain in a global capacity, which is evidenced with high standard deviations using these tools (Walker & Marchant, 2020) and could explain the discrepancies between scores obtained across the two scales (Hartrick et al., 2003), a shift towards assessing self-reported localised pain is warranted. In addition, requesting participants to report their pain considering two different time-points may also allow further depth to responses and in-turn lead to higher accuracy of pain reporting. Therefore, the present study aimed to assess the LPS against the commonly used NRS-11 and VAS to determine whether it provides greater insight into physical pain.

9.3 Method

Participants

The present study consisted of a convenience sample of men and women, recruited through social media platforms LinkedIn and Twitter as well as through the university's SONA system. Of a total of 188 participants, 57 (30.3%) were male and 130 (69.1%) were female with one (0.5%) not providing a response to this question. Participant ages ranged between 18 and 54 (M = 23.20, SD = 5.80). Guidelines for the respondent-to-item ratio have ranged from 5:1 (Gorsuch, 2013) to 10:1 (Nunnally, 1978). That is, 100 participants for a 10-item questionnaire for the latter. Using this guideline, 80 participants were aimed for the 8-item survey. As Tsang et al. (2017) recommended to utilise as large a sample size as possible, data collection was allowed to continue beyond this mark, resulting in the 188 responses obtained.

Measures

Refer to Chapter 2 for below measures:

- General Information Questionnaire (GIQ)
- Numeric Rating Scale (NRS-11; Downie et al., 1978)
- Localised Pain Scale (LPS; Appendix T)
- Visual Analogue Scale (VAS)

Reliability Statistics

Reliability statistics were calculated by conducting a Cronbach's Alpha. Analyses revealed internal consistency scores of $\alpha = .73$ for LPS(Y-1) and $\alpha = .75$ for LPS(Y-2), which are both considered acceptable (Sharma, 2016).

Data Analysis

Scores of internal consistency, correlations, factor analysis and MANOVA were conducted using IBM SPSS Statistics (Version 25).

Refer to Chapter 2 for information regarding procedure and ethics.

9.4 Results

Correlations

Correlational analysis revealed that overall pain reported in LPS(Y-1) showed a significant positive correlation with pain experienced in the past week in the NRS-11 ($r = .60$, $p = .000$). This was also the case between LPS(Y-1) and VAS ($r = .60$, $p = .000$) and LPS(Y-1) and LPS(Y-2) ($r = .63$, $p = .000$). Overall pain reported in LPS(Y-2) showed a similar significant positive correlation with NRS-11 ($r = .70$, $p = .000$) and VAS ($r = .69$, $p = .000$). Descriptive statistics are reported in Table 1.

Table 1. Descriptive statistics of overall pain across different pain questionnaires			
	N	*M*	*SD*
LPS(Y-1)	188	1.29	1.20
LPS(Y-2)	188	1.75	1.49
NRS-11	188	3.08	2.03
VAS	187	2.75	2.12

Inter-item correlation matrices for LPS(Y-1) and (Y-2) are presented in Table 2 and Table 3 respectively.

Table 2. LPS(Y-1) Inter-Item Correlation Matrix

	Y1.1	Y1.2	Y1.3	Y1.4	Y1.5	Y1.6	Y1.7	Y1.8
Y1.1	1	-	-	-	-	-	-	-
Y1.2	.128	1	-	-	-	-	-	-
Y1.3	.077	**.300***	1	-	-	-	-	-
Y1.4	**.291***	**.353***	.123	1	-	-	-	-
Y1.5	**.238***	**.385***	.109	**.340***	1	-	-	-
Y1.6	**.284***	**.256***	**.342***	**.327***	**.312***	1	-	-
Y1.7	.114	.021	.051	.128	**.201***	**.229***	1	-
Y1.8	.565	**.213***	**.388***	.430	.159	.570	**.277***	1

*****-Correlation >.20 and <.40

Table 3. LPS(Y-2) Inter-Item Correlation Matrix

	Y2.1	Y2.2	Y2.3	Y2.4	Y2.5	Y2.6	Y2.7	Y2.8
Y2.1	1	-	-	-	-	-	-	-
Y2.2	.174	1	-	-	-	-	-	-
Y2.3	**.205***	**.313***	1	-	-	-	-	-
Y2.4	**.312***	**.243***	.183	1	-	-	-	-
Y2.5	**.285***	**.216***	**.205***	**.304***	1	-	-	-
Y2.6	**.263***	**.201***	**.339***	**.377***	**.366***	1	-	-
Y2.7	.191	.176	.122	.176	.179	**.268***	1	-
Y2.8	.443	**.213***	.435	**.324***	**.201***	.502	.401	1

*****-Correlation >.20 and <.40

Inter-item correlations are an essential element in conducting an item analysis of a set of test questions, which examine the extent to which scores on one item are related to scores on all other items in the scale (Piedmont, 2014). Piedmont (2014) suggests that the average inter-item correlation for a set of items should be between .20 and .40, which represents that the items are reasonably homogeneous but not too unique from one another. As the mean average was .26 for LPS(Y-1) and .27 LPS(Y-2), this satisfies the recommendations from Piedmont (2014).

Factor Analysis

LPS(Y-1)

The 8 items of LPS(Y-1) were subjected to principal component analysis (PCA) using SPSS version 25. Prior to performing PCA, the suitability of data for factor analysis was assessed. Inspection of the correlation matrix revealed the presence of coefficients of .3 and above. The Kaiser-Meyer-Olkin (KMO) value was .67, exceeding the recommended value of .6 (Kaiser, 1974) and Bartlett's test of sphericity reached statistical significance (p = .000), supporting the factorability of the correlation matrix.

Principal components analysis revealed the presence of three components with eigenvalues exceeding 1, explaining 36.3%, 14.3% and 13.1% of the variance respectively. An inspection of the scree plot revealed an important break between points three and four and therefore using Cattell's (1966) scree test, it was decided to retain three components for further investigation. However, results from parallel analysis suggested that we accept just the first component in the factor analysis as its eigenvalue exceeds the corresponding criterion value for a randomly generated matrix of the same size (8 variables x 188 respondents). These are displayed in Table 4.

Table 4. Comparison of eigenvalues from PCA and criterion values from parallel analysis

Component Number	Actual Eigenvalue from PCA	Criterion Value from Parallel Analysis	Decision
1	2.905	1.341	**Accept**
2	1.141	1.208	Reject
3	1.045	1.102	Reject
4	0.933	1.035	Reject
5	0.654	0.951	Reject
6	0.590	0.869	Reject

The one-component solution explained a total of 36.3% of the variance. The interpretation of component 1 for this tool is that the scores record acute physical pain.

LPS(Y-2)

The 8 items of LPS(Y-2) were also subjected to principal component analysis (PCA) using SPSS version 25. The suitability of data for factor analysis was, again, assessed with inspection of the correlation matrix revealing the presence of coefficients of .3 and above. The KMO value was .76, exceeding the recommended value of .6 (Kaiser, 1974) and Bartlett's test of sphericity reached statistical significance ($p = .000$), supporting the factorability of the correlation matrix.

Principal components analysis revealed the presence of just one component with an eigenvalue exceeding 1, explaining 36.9% of the variance. The scree plot confirmed this with a clear break between component 1 and component 2 and therefore no further analysis was conducted here. The interpretation of components 1 for this tool is that the scores record pain in the past week.

Application of the tool

Assumptions

There are several assumptions that are important for one-way MANOVA (Finch, 2005). Firstly, independent variables should be categorical and dependent variables continuous. In this study, the independent variables was biological sex (male/female), and dependent variables were pain scores for each item of the LPS and then NRS-11 and VAS scores which were all continuous and therefore these assumptions were satisfied. Normality was tested using Shapiro-Wilk analysis identified that the data for each of the questionnaire items was non-normal (all $p < 0.001$), and therefore the assumption of normality was violated. However, Everitt (1979) reports that this violation has a limited impact on type I error rate for MANOVA.

MANOVA

A one-way MANOVA was run to determine whether there were any differences in pain levels between sexes for the items of the LPS(Y-1), LPS(Y-2), NRS-11 and VAS. The MANOVA revealed a significant effect of sex on the measures of physical pain, $F(1, 167)$ =

2.09, p = .008, η_p^2 = .184. Descriptive statistics and MANOVA results are presented in Table 5.

Table 5. Descriptive statistics and MANOVA depicting differences in pain levels between sexes

	Male		Female		MANOVA			
	M	*SD*	*M*	*SD*	*df*	*F*	*P*	η_p^2
Y1.1	0.64	1.15	1.03	1.35	1, 184	3.51	.063	.019
Y1.2	0.39	0.82	0.41	0.94	1, 184	0.01	.918	.000
Y1.3	0.73	1.21	0.70	1.36	1, 184	0.02	.879	.000
Y1.4	**0.13**	**0.38**	**0.72**	**1.31**	**1, 184**	**10.98**	**.001**	**.056**
Y1.5	0.21	0.56	0.23	0.79	1, 184	0.02	.888	.000
Y1.6	**0.66**	**1.03**	**1.25**	**1.48**	**1, 184**	**7.25**	**.008**	**.038**
Y1.7	0.34	0.88	0.38	1.08	1, 184	0.05	.818	.000
Y1.8	**0.91**	**1.05**	**1.44**	**1.23**	**1, 184**	**7.82**	**.006**	**.041**
Y2.1	**1.82**	**1.65**	**2.45**	**1.59**	**1, 184**	**6.05**	**.015**	**.032**
Y2.2	0.93	1.33	0.72	1.18	1, 184	1.10	.297	.006
Y2.3	1.43	1.61	1.25	1.59	1, 184	0.47	.494	.003
Y2.4	**0.66**	**1.25**	**1.67**	**1.73**	**1, 184**	**15.48**	**.000**	**.078**
Y2.5	0.55	0.97	0.55	1.19	1, 184	0.00	.999	.000
Y2.6	**1.13**	**1.34**	**1.70**	**1.73**	**1, 184**	**4.91**	**.028**	**.026**
Y2.7	0.50	1.18	0.56	1.25	1, 184	0.10	.754	.001
Y2.8	1.52	1.40	1.84	1.52	1, 184	1.82	.179	.010
NRS-11	2.79	1.99	3.15	2.00	1, 184	1.28	.260	.007
VAS	2.52	2.04	2.86	2.16	1, 184	1.02	.313	.006

Note – Significant results are highlighted in **bold.**

9.5 Discussion

Some of the most widely used tools assessing pain such as NRS-11 and VAS are limited by only assessing overall acute pain. While there is merit in obtaining this information, this study aimed to develop a pain scale that localises pain while also obtaining information regarding overall pain. Initially, this new tool seems promising, bearing acceptable internal consistency scores (Sharma, 2016) and correlation analysis revealed both aspects of overall pain in the LPS are significantly positively associated with NRS-11 and VAS suggesting that they obtain the same information. Additionally, the inter-item correlation matrix appears to be positive, satisfying Piedmont's (2014) recommendations regarding homogeneity and heterogeneity among scale items.

The use of this tool has been demonstrated by providing an example of analysing the data obtained in this study. It was revealed that females reported higher scores of physical pain across 6 of the 16 items that comprise LPS(Y-1) and (Y-2). These included headache over the past week, acute overall pain, and then abdominal and back pain across both time-points. Firstly, it is often reported that females report higher levels of physical pain (Debi et al., 2009; Keogh & Eccleston, 2006), and this further supports those findings. Moreover, it is important to understand these pain levels given the link with pain and poorer mental health (Walker & Marchant, 2020; Walker & McKay, 2022).

Additionally, we have found differences in various areas of physical pain, where this has not been found using the NRS-11 and VAS. This highlights the necessity of this tool as this analysis provides evidence that there is potentially important information regarding physical pain being overlooked using the NRS-11 and VAS. As females report worse abdominal and back pain in both (Y-1) and (Y-2), these may be areas that are of utmost importance, and could be larger contributors to elevated depressive symptoms (Walker & McKay, 2022). Therefore, future studies ought to use this tool to determine the predictive capability of mental health decline using localised pain information.

Most importantly, overall scores of pain are visibly lower in both aspects of the LPS (Y-1.8 & Y-2.8) compared to the NRS-11 and VAS. This finding is perhaps due to the reductionist nature of the NRS-11 and VAS, by limiting respondents to reporting their pain as a whole, whereas the LPS allows the exploration of different areas of pain across different time-points. When respondents are thinking more deeply about different areas of pain, this may lead to more accurate reporting of their overall pain, whereas NRS-11 and VAS may inflate these. As females report significantly higher scores of pain on (Y-1.8) the item responsible for recording overall acute pain, the LPS may be a more robust tool than the NRS-11 and VAS that found no difference between sexes here.

It must also be noted that factor analysis is usually performed on much larger datasets, however, the KMO values and Bartlett's test of sphericity supported the factorability of the correlation matrix of both LPS(Y-1) and LPS(Y-2). That said, analysis revealed a one-factor structure for both LPS(Y-1) and (Y-2), which may simply indicate the heterogeneity of the items, though not so much so to be concerned given the findings from the inter-item correlation matrix. Therefore, the factor analysis suggests that the items of LPS(Y-1) represent acute physical pain while (Y-2) represents physical pain over the past week.

9.6 Limitations

The limitations of this study must be addressed. Although the sample is justified, more participants would ensure stronger conclusions could be made, and future research should aim to obtain more respondents. Additionally, the sample is comprised heavily of female participants, with over two thirds of the sample selecting this as their biological sex. As we know there are important differences in pain experienced between male and females (Walker & McKay, 2022), this can make it difficult to generalise the tool that we are proposing here. It may be that this tool is more suitable for females than males and therefore may not be beneficial to use with males. Further research utilising a more even sample regarding biological sex could help determine any differences between biological sex that could better indicate its usage. Additionally, the current sample size did not allow for invariance testing which would be an important next step. Meade (2005) suggests a minimum 200 participants per group (e.g. biological sex) and therefore this sample falls far below this total. Collecting more data using this tool would allow this analysis to be conducted, amending this limitation.

Another limitation of this tool is that both LPS(Y-1) and (Y-2) are completed at the same time. That is reporting level of physical pain *right now* and *in the past week,* respectively. Therefore, the data obtained in LPS(Y-2) may be influenced by participants responses to the same items in (Y-1) and may not be a true account of physical pain experienced in the past week. That said, the scores of acute physical pain in NRS-11 and VAS were visibly higher and found no difference between sexes. Therefore, the use of

LPS(Y-1) is justified regardless of any limitation of LPS(Y-2). At this stage, findings from LPS(Y-2) may be inferred with caution.

9.7 Practical Implications

The aim of developing a new pain scale is to provide a more nuanced and meaningful self-report of physical pain. As we have seen the NRS-11 and VAS so often used to measure physical pain, it is concerning that we find differences between sexes in overall acute pain in our scale (LPS) that are not captured in the NRS-11 and VAS. There would have been no differences found in this dataset had we not used the LPS. Moreover, we identify different areas where females report higher scores of physical pain, providing further insight into what areas of physical pain are impacting the individual. In future, the LPS should be examined to determine whether different areas of physical pain predict poorer mental health, building on the work of Walker and McKay (2022) that provided evidence of this using the NRS-11. While there is value in that work, identifying which areas of pain are associated with elevated depressive symptoms will only refine the support that can be offered.

9.8 Conclusion and Future Directions

The NRS-11 and VAS have often been used to measure physical pain (Hartrick et al., 2003; Lau et al., 2013; Sigurdsson et al., 2021; Walker & Marchant, 2020). However, they are limited to recording a measure of overall acute pain. The LPS that we propose not only records this across two different time-points, but information pertaining different areas of physical pain are also obtained. This new information gathered from this tool may provide valuable insights that could shape the behaviours of sports coaches with their athletes and potentially inform us on how physical pain changes over time. Although the present study uses a modest sample size, it bears an acceptable internal consistency, a good average inter-item correlation matrix, and positive signs of factorability. In addition, there is also good evidence of its use, with females found to report higher scores abdominal, back, and overall acute pain as well as headache. Therefore, the LPS is advised to be used ahead of the NRS-11 and VAS, to gain further insight into physical pain in larger sample sizes.

Chapter 10: Discussion of project and concluding remarks

10.1 Discussion

At present, there is an abundance of literature on the negative outcomes of SRC, as well as these outcomes becoming common knowledge in the general public, perhaps due to increased media coverage of this issue. Ex-professional rugby player Steve Thompson, who won the Rugby World Cup with England in 2003, now suffers from early-onset dementia and probable CTE. Thompson was diagnosed in December 2020, aged 42, and claims to having no memory of the world cup victory he was part of. Last year he published a book titled "Unforgettable: Rugby, Dementia and the Fight of My Life" as well as a BBC documentary titled "Head On: Rugby, Dementia and Me" which were both well received.

In 2002, former West Bromwich Albion striker Jeff Astle died at the age of 59 from CTE, whereby the coroner's verdict was "death by industrial injury" thought to be from consistently heading the ball. Astle was well-known for his heading ability, and it was considered one of his greatest attributes. Since then, daughter Dawn Astle has set up the Jeff Astle Foundation and has consistently campaigned for better protection of players from the PFA and governing bodies as well as holding the sport accountable. Alongside this, almost half of the starting 11 England side that won the World Cup in 1966 have too suffered from dementia thought to be due to heading the football. It has claimed the lives of Ray Wilson, Jack Charlton, Nobby Stiles and Martin Peters, while Sir Bobby Charlton continues to suffer from the illness. This media attention depicts how the consequences of head injury in sport are becoming better known within the general public.

Therefore, due to this increased attention, the broadest aims of this project were to examine the influence that SRC has on mental health, cognition, and quality of life. From study 1, it appears that concussion is responsible for depression but that the existence of physical pain after concussion can exacerbate depressive symptoms and lower quality of life scores which could suggest that pain may be of more interest to researchers in this field. Although it may seem obvious that pain often accompanies concussion as Provance et al. (2020) suggests, it is surprising that the two are rarely investigated simultaneously in the literature. This project is unique in doing so and reviews the quantity of previously published work in this area that assess the impact of concussion history without considering the influence of physical pain and vice versa. Therefore, this project argues for the importance of taking into consideration the co-existence of pain as a key contributing factor in future concussion studies.

With the influence of physical pain on mental health and quality of life found in study 1, study 2 aimed to investigate this association further. Grouping participants by pain levels using Downie et al.'s (1978) recommendations, it was found that increasing levels of pain leads to worse depression, higher anxiety, and lower quality of life, illustrating a clear link between pain and mental health and quality of life. Interestingly here, concussion history had no impact on these outcomes, which would again suggest that pain may be more relevant in this area of research. As much of the concussion literature tends to overlook the potential influence of physical pain, this project attempts to addresses this shortcoming by assessing the role of pain in athletes that have and have not sustained concussion and how this can impact on the mental health and quality of life of these individuals.

Based on the findings of studies 1 and 2, pain could not be overlooked and was, again, included as a covariate in study 3. As study 1 and 2 had established that pain may be more relevant within concussion literature than was currently thought, study 3 built on this by investigating what impact SRC and pain had on cognitive processes. Consistent with studies 1 and 2, it was found that pain was associated with poorer mental health (depression and anxiety) and reduced quality of life whereas SRC history was not. By contrast, SRC history was related to poorer cognitive flexibility but was not associated with changes to mental health and quality of life. This provides a clearer insight into the processes following concussion and pain on the three broad outcomes, mental health, cognition, and quality of life. Much of the “add-on” literature suggests that concussion leads to reductions and impairments to the three broad outcomes mentioned, however, overlooking physical pain as a factor for influencing these three outcomes can lead to misinterpreted conclusions. Study 3 therefore, provides a more nuanced explanation, suggesting that concussion is responsible for impaired cognitive ability, and physical pain is responsible for poorer mental health and reduced quality of life. Therefore, with this we can better understand what to expect in athletes that have sustained concussion, are experiencing physical pain, or often likely both.

Nevertheless, it would be naïve to suggest a one-to-one relationship between these factors and assume that all concussed athletes would necessarily display long-lasting impaired cognition. Similarly, it would be naïve to conclude that those experiencing acute physical pain will always present poor mental health and reduced quality of life. For this reason, it is necessary to understand how the negative consequences that have been highlighted in studies 1-3 may change over time. By trying to understand the intricate relationships between these factors and how they interact with each other, we can better inform athletes, coaches, parents, and peers of what may be expected at different points post-concussion and/or when experiencing physical pain. In study 4 we found some evidence of decline in performance in the accuracy of the cognitive flexibility task between T1 and T2. However, at the same time we found some overall improvement in the speed of completing the same task at T2 testing. This was attributed to Fitts’ (1954) law of a speed-accuracy trade-off. Corroborating the findings of studies 1-3, in study 4 we found that physical pain was associated with elevated mental health symptoms and reduced quality of life. As pain did not have much influence over cognitive task performance, this further supported our argument that physical pain can be more responsible for poorer mental health and reduced quality of life whereas concussion, per se, can lead to cognitive impairment in some athletes.

Despite these negative outcomes, there are still many that engage in different contact sports, whereby the risk of experiencing these negative neurological outcomes is heightened. As studies 1-4 further highlighted the negative consequences of sustaining concussion and experiencing physical pain, this led to this project aiming to investigate the attitudes and knowledge base of concussion (study 6). A sample of rugby players was obtained due to this comprising a large portion of the sample used in studies 1-4 and with concussion highly prevalent in rugby. A poor duty of care, poor attitudes and knowledge and frequent continued participation following suspected concussion were key themes developed in this study. From these findings there is potentially a sequalae to each of these themes, whereby poor duty of care from parents, coaches, officials, and other teammates contributes towards poor attitudes and knowledge of concussion. This poor knowledge base and attitude towards concussion could then lead to continued participation following suspected concussion. Therefore, appropriate duty of care towards amateur players is paramount and could play a significant role in reducing the prevalence of concussion in amateur rugby. That is, with the stance that prevention of concussion is better than the cure.

The poor attitudes towards concussion in amateur rugby players that were revealed in study 6 is a concern given the negative outcomes that are presented in studies 1-4. Sportspeople, particularly amateurs, possess unsafe negative attitudes towards concussion and it may be due to a lack of education, and not truly understanding the risk they are taking. Therefore, due to a gap in the literature, study 5 attempted to provide odds ratios for the likelihood of developing depression using various risk factors. In this study, we found that taking part in contact sports leaves sportspeople 71 times more likely to develop depression than those that do not engage in sport at all. This finding is an important development given evidence that physical activity promotes positive mental health (Callow et al., 2020; Saxena et al., 2005). Study 5 also found those that took part in non-contact sports were over 4 times more likely to develop depression than those that took part in no sport. With SRC history revealing a 57 times greater likelihood of developing depression, this highlights the impact this project will have. This impact is also demonstrated with a poster presentation of this study having been presented at the 6th International Consensus Conference on Concussion in Sport in Amsterdam, The Netherlands in October 2022. Although there is value in studies 1-4 in providing insight into differential roles of coexisting concussion and pain, study 5 provides a clear understandable risk assessment for sportspeople. If athletes are made aware that sustaining concussion can increase risk of depression 57 times and engaging in contact sports increases this by 71 times, they may be more likely to reconsider engaging in contact sports whereby the risk of concussion is elevated. At present, they are consistently told there is an increased risk of negative outcomes following concussion, but it is unlikely they understand what risk. Study 5 clearly demonstrates this significant risk and communicating this effectively to athletes is extremely important and may be a useful way of reducing the prevalence of concussion, rather than treating the outcomes.

Physical pain is consistently shown to have a detrimental impact to mental health throughout the different studies and is replicated again in study 5, whereby participants were 1.4 times more likely to be depressed for every score of physical pain they reported on the NRS-11. Given that the NRS-11 is an 11-point Likert scale (0-10), although it may not sound like a great difference at face value, it is when scores ranged from 0-8. When participant A reports a score of 0 and participant B reports a score of 8, this would mean that participant B is over 20 times more likely to be depressed than participant A. Therefore, the importance of physical pain in this project, and in sport, cannot be underestimated. When physical pain has such a negative influence on mental health, and quality of life as highlighted in studies 1-4, it has predictive potential. It is for this reason that we suggest that sports coaches, particularly for contact sports, should utilise pain questionnaires not only to understand on the surface, the level of pain their athletes are experiencing, but also with the knowledge that higher scores can indicate mental health decline (Walker & Marchant, 2020; Walker & McKay, 2022).

It should also be noted that there is evidence that female athletes present elevated depressive symptoms at lower levels of physical pain than male athletes (Walker & McKay, 2022). This difference is potentially due to better reporting from female athletes, and indicative of males being "head strong" (Liston et al., 2018), which explained poor attitudes and continued participation with suspected concussion in study 6. This finding is supported in study 5 whereby female participants were almost 3 times more likely to be depressed than males. Taken together, this would indicate that pain questionnaires ought to be used with athletes to provide an indication of mental health in the performer, however the biological sex of the athlete should also be considered. Further research could attempt to uncover how much of a difference there are between sexes and identify cut-off points for each sex whereby they present different levels of risk to their mental health.

That said, the NRS-11 that was used throughout this project, and in much of sporting literature (Walker & Marchant, 2020), may be too simplistic. For example, it only captures acute pain overall pain from 0-10. Therefore, study 7 sought to amend this and introduce a new pain scale that can be used within and outside of sport that attempts to localise the physical pain as well as measuring this across two different time-points. Based on our analysis of 188 participants, we present a sound basis for a new pain questionnaire that localises pain "right now" and "in the past week" with acceptable internal consistency scores for each sub-scale. We found meaningful differences between sexes regarding abdominal and back pain at both time points, as well as for acute overall pain and headache in the past week. Females reported higher scores than males on each of these items. Compared with commonly used instruments like NRS-11 and VAS, which found no difference between sexes, our scale provides useful information that is otherwise lost. This improvement is particularly pertinent for item (Y-1.8) that asks participants to report their level of overall physical pain right now compared with NRS-11 and VAS that ask for a score over the past week. While our scale also finds no statistically significant difference on this measure over the past week, it certainly highlights the need to measure physical pain asking participants to consider different time-points.

Additionally, we present the factorability of our scale with KMO's over .6 (Kaiser, 1974) and a significant Bartlett's test of sphericity. However, further factor analysis revealed a one-factor structure for both sub-scales suggesting that the pain they were reporting represented what was asked of participants; pain experienced "right now" or "in the past week".

We therefore argue that the proposed LPS should be used ahead of the commonly used NRS-11 and VAS. We pose this due to the LPS identifying that females score higher on 6 of the 16 items where the NRS-11 and VAS found no differences at all. It is for this reason we feel that there is important information regarding experienced physical pain that is being lost using the NRS-11 and VAS that ought to be explored. This information cannot afford to be lost given the impact that pain has on elevated depressive symptoms in general (Walker & Marchant, 2020) and for females (Walker & McKay, 2022). Therefore, further research ought to be conducted using this new proposed tool to uncover different types of physical pain predicting mental health decline. This could lead to coaches being able to more accurately predict athletes that require psychological and emotional support.

Beyond this, we also ran analysis on the quality of life measures used in this project. As highlighted in Chapter 1, the ALQS was utilised alongside the SF-12 as a more focused tool of quality of life in athletes. However, as the ALQS is a much newer tool it has previously been used less often than the well-validated SF-12. Therefore, this project wanted to use both in juncture to assess their use with post-concussed samples. Sixty-seven athletes (Male n = 51, age M = 24.78, SD = 5.84, Female n = 16, age M = 22.19, SD = 3.43) completed both ALQS and SF-12 questionnaires (Cronbach's alpha = 0.87 for both scales). Over 80% of these athletes reported having sustained concussion previously (n = 54). Concussions occurred between 1 and 48 months prior to taking part in the study (M = 18.62, SD = 14.24). A two-way MANOVA revealed that there was an effect of sex, $F(1, 63) = 5.88$, $p = .018$, $\eta_p^2 = .085$, and concussion history $F(1, 63) = 9.52$, $p = .003$, $\eta_p^2 = .131$ on SF-12 scores whereas there was no effect of sex and concussion history on ALQS scores ($p > .05$). There was also no interaction effect of sex and concussion history on both SF-12 and ALQS scores ($p > .05$). Descriptive statistics are displayed in Table 1.

Table 1. Descriptive statistics depicting the effect of sex and concussion history on quality of life

	Sex	Concussion History	*n*	*M*	*SD*
ALQS	Male	Yes	43	74.16	13.78
		No	9	70.63	14.60
		Total	62	73.61	13.82
	Female	Yes	11	64.55	15.11
		No	5	77.40	11.46
		Total	16	68.56	15.00
	Total	Yes	54	72.20	14.45
		No	13	73.23	13.41
		Total	67	72.40	14.16
SF-12	Male	Yes	43	25.70	5.97
		No	8	28.63	6.19
		Total	51	26.16	6.03
	Female	Yes	11	17.73	6.00
		No	5	27.00	5.48
		Total	16	20.63	7.19
	Total	Yes	54	24.07	6.75
		No	13	28.00	5.75
		Total	67	24.84	6.71

These findings are similar to what we found in Chapter 9 comparing the LPS with NRS-11 and VAS. Here we demonstrate that there are important implications regarding the role of sex and concussion history on quality of life, but this is only identified using the SF-12 and is overlooked using the ALQS. Data analysis in the rest of this project would be limited to just athletes if we included ALQS scores (as only athletes completed this tool) and therefore it was decided to omit this tool from data analysis. These findings here justify this decision as it is evident that the SF-12 is a more robust tool for assessing quality of life and should be used with athletes in future research when assessing concussion history.

10.2 General Issues/Limitations

Self-selection bias

There is a risk of self-selection bias within this project, which may affect the results of each study due to the voluntary nature of recruiting participants (Alarie & Lupien, 2021). This technique may explain why we find abnormally larger prevalence rates of meaningful depressive symptoms throughout the project. As the advertisements refer to the project intending to examine the mental health, cognition, and quality of life of post-concussed participants, it could be that those that have had concussion and experienced mental health issues, or changes to their cognition, may be more likely to take part in the project. By contrast, those that have sustained concussion that have not experienced any differences to the three outcomes we were measuring may not have been interested in taking part, and therefore this important part of the sample is lost in this project. However, self-selection bias is common in concussion research (Pieper & Garvan, 2014) and therefore could be expected. Self-selection bias is also arguably present in the control sample in our project, whereby those that had not sustained concussion but had experienced poor mental health for example may have been more interested in taking part. We see above average mental health symptoms in the control sample in study 1 and therefore, self-selection bias could be counterbalanced in this project deeming our findings valid.

Measuring Concussion

Another aspect of the project that required careful thought regarded the measuring of concussion. One method of doing so would be to obtain medical reports whereby athletes have received an official recorded diagnosis of concussion. While this would be beneficial in confirming concussions had happened, this poses threats to sample size, as the likelihood of obtaining enough participants, within a time-period whereby concussion having an impact on the three outcomes being meaningful, is low. Additionally, to be able to do this, the project would have had to obtain NHS ethics as well as departmental ethics from the university, which is a lengthy process. The onset of the COVID-19 pandemic led to the reframing of this project methodologically which required a large amendment to ethical approval from Edge Hill University. This process took approximately four months from March-July 2020. Given the pressures on the NHS in this period, it was deemed that gaining ethical approval from the NHS regarding concussion research would have taken even more time away from the data collection period. Therefore, self-report of concussion was utilised in this project with the likelihood of participants making false claims about having had concussion or withholding their concussion history considered extremely low. As well as this, the PCSS was used to assess the symptoms that post-concussed participants had experienced at the time of concussion, with a score of ≥7 deemed as a genuine concussion, with all participants that reported having had a concussion scoring above this value.

COVID-19 Implications

The impact that COVID-19 had on the project must be discussed. In February 2020, the researcher passed the project registration VIVA that included a research proposal with a different methodology to that that has been used. Originally, the main study was intended to be conducted face-to-face in the psychology labs at EHU. However, given, the onset of the

COVID-19 pandemic in the UK in March 2020, a remote approach was necessary. It is noteworthy that the time taken to ensure the study could be ran smoothly meant that data collection did not commence until June 2020, as is discussed in ***Athlete Status*** below.

Due to the nature of the pandemic, and the impact that it has had on mental health (O'Connor et al., 2021) and quality of life (Garrigues et al., 2020), it was necessary to add further controls to the GIQ. These included COVID-19 diagnosis, bereavement, furlough status, physical activity/sporting participation pre- and post-covid onset, alcohol consumption pre- and post-covid onset, and history of mental health disorders pre- and post-covid onset. With evidence of the lockdowns in the UK in response to the COVID-19 pandemic negatively impacting our main three areas of interest in mental health (Bird et al., 2021), cognition (Suárez-González et al., 2021), and quality of life (Siette et al., 2021) it must be considered that this could have influenced the results in this project. Having said that, everyone was exposed to the pandemic regardless of concussion history. Although mental health symptoms may have risen, it is unlikely that this will have only occurred in the control sample, and therefore the results in this project can be inferred without caution.

Athlete Status

Defining terms can be difficult within research (McAuley et al., 2022) and the term "athlete" could be considered ambiguous. What one may deem as an athlete, another may not, which is likely due to what people consider a sport. However, as we were interested in the emotional and cognitive states of our sample, all that mattered was whether participants saw themselves as athletes and dealing with the highs and low associated with sport (Thatcher et al., 2011), rather than whether someone else considers them to be an athlete per se. For this reason, we decided on the self-identification of athlete in this project. This variable was of course impacted due to the onset of the COVID-19 pandemic in the UK in March 2020, with the opportunity to engage in sport nil. Although unavoidable, the reduction of playing time for athletes during this period of the pandemic could have impacted the findings. There are many factors associated with playing sport, whether they help or exacerbate mental health symptoms and impact quality of life. However, sport largely re-commenced in June 2020 in the UK with few stoppages after this period, and therefore, most of the data was collected while participants were engaging in sport despite the COVID-19 disruptions.

Sex differences in concussion

Recently, there have been indications that sex may play an important role in the severity of concussion experienced (Bunt et al., 2021). Bunt et al. (2021) suggest that females have are exposed to higher severity of concussion, however this may be due to females being more likely to report increased symptom severity than males (Bunt et al., 2020). In contrast, there is evidence that males suffer worse from the consequences of concussion such as white matter alterations (Wright et al., 2021), cerebral blood flow changes (Hamer et al., 2020), and recovery times (Churchill et al., 2021).

In this project, there were no sex differences found in symptom severity measured using the PCSS, the number of concussions sustained, and recovery periods. However, this was likely to be the case due to the low sample of post-concussed females. As this was not the main priority in this project, it is normal that an uneven split of sex is reported in the total sample. Research specifically investigating sex differences in concussion will recruit a more even sample between sexes. However, this had to be acknowledged within this project as much of the literature into concussion is predominantly male-oriented, and this project follows suit with this male bias.

Sport where concussion is more frequent

Like self-selection bias and male bias, there is also a rugby bias in this project. This, again, is not surprising due to the voluntary nature of recruitment. Just as there is no way of limiting participation of those with a vested interest in taking part due to having experienced mental health issues following concussion and limiting males taking part to recruit a more even sex sample, there is also no way of limiting participants by their predominant sport. As rugby has the highest prevalence of concussion in both match play and training (Prien et al., 2018), it is normal that rugby players compose half of the total athlete sample. Therefore, the findings are perhaps more relevant to rugby players than those that sustained concussion in other sports.

10.3 Practical Implications

There are numerous practical implications that can be taken from this project. Physical pain has consistently been found to negatively impact mental health and quality of life in this project. This supports previous research that has found similar (Humo et al., 2019; Nekovarova et al., 2014; Walker & Marchant, 2020), particularly Walker and McKay (2022) that found female athletes will experience elevated depressive symptoms at lower levels of physical pain than male athletes. Using the information found in studies 1-5, we could argue that the use of pain questionnaires within sports teams may be useful in providing insight into the emotional state of athletes. The way that pain questionnaires are framed to athletes, however, is important. It could be that athletes may be more honest on these questionnaires than mental health surveys themselves. However, the practicalities of this may brought into question given the extensive amount of data that is utilised in elite sport to inform team selection (Fiander et al., 2021; Roca et al., 2022). As athletes are aware that they are being so closely monitored, and that this could have implications to their chances of selection, there could be a reluctance to disclose truthful information regarding pain. As with injury, athletes will not want to be perceived as weak (Wilson et al., 2021), and this could also promote unwillingness to disclose pain symptoms. That said, due to obvious differences in facilities and finances in amateur sport, there are much less data used to inform team selection, and therefore our recommendations may still be beneficial in the amateur domain. We suggest that implementing this practice with the assurances that it is to protect player welfare physically and emotionally and for the benefit of the team may be more successful.

Although the NRS-11 and VAS are widely used tools and the NRS-11 was utilised throughout this project there are indications that they may be too simplistic (Safikhani et al., 2018). Therefore, after providing evidence that pain is associated with poor mental health and reduced quality of life and suggesting the use of pain questionnaires in sports teams to protect player welfare and sporting performance, this project also developed a new pain scale. The LPS can be viewed as a more useful tool than the NRS-11 and VAS, as demonstrated in Chapter 9. We argue that the NRS-11 and VAS are reductionist in nature (Cholewicki et al., 2019) whereas the LPS allows respondents to consider their physical pain more deeply by asking them to report on different areas of their pain and think about this pain at different time-points, acutely and retrospectively.

Additionally, we demonstrate in study 6 that amateur rugby players may possess unsafe attitudes of concussion which may be due to a poor duty of care and incompetence from non-players. Players and coaches may think that they have sufficient knowledge of concussion (Kraak et al., 2019; Salmon et al., 2021) as many will have competed in rugby themselves and believe they have avoided negative consequences. However, it may be that players and non-players are not aware of the true dangers of concussion. In study 5 we developed a simple risk metric, that is easy to communicate to athletes the likelihood of developing depression following a concussion. We also present odds ratios for other factors such as biological sex, physical pain, and engaging in contact sport and non-contact sport. Here we found that females are more likely to display depressive symptoms than males and those engaging in contact sports are at significantly higher risk as well. As predicted, higher levels of physical pain predict greater chance of developing depression. This simple risk metric is the first of its kind and should be communicated effectively across amateur rugby teams in the UK and beyond to improve knowledge of concussion and the real risk that taking part in rugby poses. This in-turn would help alleviate the poor attitudes that we report in study 6.

Moreover, in study 6 participants often cited the size of rugby teams as an issue, reporting that a reason for their continued participation was so not to let the team down. Starting line-ups of rugby league and rugby union teams are thirteen and fifteen respectively, and therefore amateur rugby relies on many people to be committed to the club. With no financial benefit it may be that other commitments take precedent at times, leaving amateur rugby teams with few or even zero substitutes in a match. This then increases the pressure on players to continue with suspected concussion and for those around them to ignore or underplay concussion symptoms. Therefore, this project could inform policy in that the Rugby Football Union and Rugby Football League should impose law changes that state a certain number of players must be available for the match to begin. If this requirement is not met, the match should either be postponed, or a rugby sevens match may take place if agreed by both teams.

Most importantly the project dissociates the impacts of concussion and pain from one another. We now have a deeper understanding of some of the negative consequences post-concussion, with our argument that concussion is more responsible for cognitive impairment than pain and pain is more responsible for poor mental health and reduced quality of life than the concussion. With this information, sports coaches are now at an advantage in understanding their athletes cognitive and emotional states based on these factors. For example, an athlete that has sustained concussion but reports no physical pain is likely to have lesser cognitive ability. An athlete reporting higher levels of physical pain but has no history of concussion is likely to have poorer mental health and lower quality of life, particularly in female athletes (Walker & McKay, 2022) but may not demonstrate any cognitive impairment. Those that have sustained concussion and are reporting levels of physical pain are likely to present negative impacts to the three broad outcomes.

10.4 Conclusions and Future Directions

With evidence that concussion is associated with poor mental health (Kerr et al., 2014; Kontos et al., 2016; Rice et al., 2018), impaired cognitive ability (Bleiberg et al., 2004; Guskiewicz et al., 2005; McInnes et al., 2017), and reduced quality of life (Emanuelson et al., 2003; Gard et al., 2020; Popov et al., 2022), this project aimed to address a gap in the literature by being the first to assess these three broad outcomes in the same sample. In addition, there is also evidence that physical pain is associated with the three outcomes, poor mental health (Walker & Marchant, 2020; Walker & McKay, 2022), impaired cognitive ability (Hageman et al., 2014; Moriarty et al., 2016), and reduced quality of life (Niv & Kreitler, 2001). As concussion and physical pain often co-exist (Mollayeva et al., 2017; Provance et al., 2020), it is questionable as to why the two are not always investigated simultaneously. Therefore, this project has attempted to address this gap too by being the first to assess these two factors with these three broad outcomes. As the literature stood, it was unclear as to which factor led to which outcome as the research that these claims were based on did not control for the other. However, this project has improved our understanding here as we pose that concussion is responsible for cognitive impairment and physical pain is responsible for poor mental health and reduced quality of life. In future, concussion research should always include the influence of physical pain given the likelihood of it confounding, and when doing so the newly developed LPS should be used to identify information regarding physical pain and in-turn potentially risk of poor mental health that may have been overlooked if using the NRS-11 or VAS.

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12. Appendices

Appendix A – Participant Information Sheet

How does concussion in sport impact our emotions, the way our brains use information and our quality of life?

Background: A concussion is a temporary injury to the brain caused by a bump, blow or jolt to the head or body. In sport, you might have heard it called a "knock" or having your "bell rung". A concussion usually only lasts a few days or weeks, although it sometimes needs emergency treatment, and some people can have longer-lasting problems. Signs of concussion usually appear within a few minutes or hours after a head injury, but sometimes they can take a few days. Symptoms include loss of consciousness, headaches, dizziness, vomiting, confusion, memory loss, trouble balancing, mood swings and blurred vision.

Research has shown us that concussion can significantly impact people's health and wellbeing. In particular, there is evidence that sport concussion can influence the emotions that we feel and the way our brains function ("cognition"). This can then impact quality of life. This study aims to investigate whether people who have had a sport-related concussion experience depressed mood and/or show changes in cognition, compared to people who have not had a concussion. It is also of interest as to whether those who have had concussion report lower quality of life than those who have not.

Eligibility Requirements:

In this study we need athletes (people that have competed in sport at least once a week during the past three months **or would usually do so without COVID-19 disruptions**) and non-athletes. We are interested in whether you have sustained a sport-related concussion in the past, even if you were an athlete when it occurred and are not still defined as an athlete now. We will ask you to self-report whether you have experienced a concussion when playing sport and if you have sustained one away from sport. If you do think you had a concussion, it does not matter whether a doctor diagnosed it or not, a simple questionnaire during the study will measure this.

To participate in this study, you can either be an athlete or a non-athlete. This means that if you have not competed in sport once a week for the past three months you can still participate, as we are also interested in any differences between those that play sport and those that do not, regardless of concussion history.

Exclusion criteria: If you have sustained SRC/concussion in the past 28 days you cannot participate in this project. We do, however, encourage you to take part when this period has passed.

What do I need to do? If you are eligible and would like to participate, following providing informed consent you may proceed. This will involve taking part in two different sessions (one at home, one on a video call with the researcher). The first session includes a series of questionnaires and different computer tasks. The questionnaires will ask you about your concussion history, will measure symptoms of depressed mood and anxiety, your positive and negative affect and quality of life. The computer tasks will measure different areas of cognition, particularly executive function. The second session will take place over a video call with the researcher and will include more computer tasks as well as tests the researcher must administer verbally. The study should take approximately 120 minutes to complete split equally between sessions. You will be reimbursed £16 for your time. This can only be paid via PayPal.

Are there any risks to participating? As we are investigating topics such as changes in mood and cognition as a consequence of concussion, this could cause you some psychological discomfort or concern. People who have had concussion have reported being more sensitive to light. As this study will take place on a computer screen, you are advised to stop immediately if you feel unwell, dizzy or want to stop for any other reason.

Are there any benefits to participating? By taking part in this study, you are helping us gain a better understanding of the emotional and cognitive changes in the brain after concussion. In addition, we may be able to pin-point the likelihood of developing depression following a concussion. Also, many people are not aware of how serious concussion can be, and by taking part you are helping raise awareness of the dangers of concussion and how important it is to prevent it from happening in sport.

There is also the opportunity to take part a second time, 6 months after your first visit. This is to compare your results between the two different time points to see whether things have changed. If you wish to do so you can provide your contact details on the consent form and the lead researcher will be in touch inviting, you to take part again. Just because you have taken part in this one does not mean you have to take part again, likewise, providing your contact details for a second time does not mean you have to take part again. If you receive £16 for this study, you will receive £24 for doing it again. If you receive course credits you have the option to select course credits again or £16.

What will happen to the information I provide? All the data collected from you will be kept **confidential.** Only the researchers will have access to the information you provide, and it will be for the purposes stated on this screen/sheet. Data from the questionnaires will be stored safely in Qualtrics with limited access and will be password protected. Similarly, data collected from the computer tasks will be stored safely on the researchers' university Z drive in encrypted/password protected folders as well as in the personal participant Google Drive that participants will upload their data to.

Note that you are free to withdraw from the study without having to give reason. This means that you do not have to take part and that you can stop at any time during the study.

If you wish to withdraw your data you are free to do so up until two weeks after you took part. The deadline for this will be at 23:59, 14 days after you took part, and you can do so by contacting the researcher by email (walkerd@edgehill.ac.uk), simply stating you wish to withdraw your data and providing your unique ID (Six-digit number. Two digits of month of birth + last two digits of year of birth + first two digits of postcode) used during the study. The researcher will inform you by email when your data has been destroyed. The researcher will keep a record of participants that have requested to withdraw their data, and this will again be safely stored on the researchers' university Z drive in encrypted/password protected folders

You are welcomed to contact the researcher if you have any questions before taking part in the study.

Lead Researcher: Daniel Walker (walkerd@edgehill.ac.uk)

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Dr. Adam Qureshi (qureshia@edgehill.ac.uk)
Dr. David Marchant (marchand@edgehill.ac.uk)

Chair of Departmental Ethics Committee: Dr. Andy Levy (levya@edgehill.ac.uk)

Appendix B – Participant Consent Form

Before we begin, it is essential we obtain full informed consent from participants.

Have you:

	YES	NO
Been given information explaining the study?	○	○
Had an opportunity to ask questions and discuss the study?	○	○
Received satisfactory answers to all questions you asked?	○	○
Received enough information about the study for you to decide about your participation?	○	○
Sustained concussion in the past 28 days?	○	○

Are you:

	YES	NO
18+ years of age	○	○

Do you understand:

that you are free to withdraw from the study and free to withdraw your data

	YES	NO
Until two weeks after participation (23:59, 14 days after taking part)	○	○
Without having to give a reason for withdrawing?	○	○

There is also the chance of participating again, after six months to see any changes between your scores. If you are interested, please write your email address or phone number below and the researcher will be in contact with you. This is optional. Leave this section blank if you do not wish to be contacted. By giving your details you are only consenting to being contacted, not to participate for a second time. If you choose at a later date that you do not want to participate, that is fine and will not affect the conditions of this consent form. If you receive £16 for this study, you will receive £24 for doing it again. If you receive course credits you have the option to select course credits again or £16.

Appendix C – Participant Debrief Form

How does concussion in sport impact our emotions, the way our brains use information and our quality of life?

Firstly, thank you for taking part in this study.

Background: Research has shown a link between concussion and depression (Yang, Peek-Asa, Covassin & Torner, 2015) as well as concussion and cognitive impairments (Brush, Ehmann, Olson, Bixby & Alderman, 2018). This study aims to investigate whether there is a difference in depression symptoms and cognitive functioning between those that have experienced concussion and those that have not, whilst also aiming to look at the quality of life between these groups. The Center for Epidemiological Studies Depression Scale (CESD) was used to measure symptoms of depression and the computer tasks recorded executive functioning. The Athlete Life Quality Scale (ALQS) and the Health Related Quality of Life Short Form – 12 (HRQL SF-12) were used to record quality of life. The tasks I asked you to remember was used to measure prospective memory or remembering to do something in the future. It is predicted that those that have not experienced concussion are more likely to have lower scores of depressive symptoms in comparison to those that have experienced concussion. They are also expected to record poorer accuracy and higher reaction times for the computer tasks and report lower quality of life. It is also predicted that the non-concussed group will remember the post-it note more often than the non-concussed group. Depression has also been linked with anxiety and the way in which we perceive events around us, therefore, the State-Trait Anxiety Inventory (STAI) and the Positive and Negative Affect Scale (PANAS) were also included in the questionnaire. It is predicted that those with higher scores of depression will also score highly on anxiety and negative affect. This project aims to further investigate whether concussion has a negative impact on mental health and cognitive functioning, whilst also aiming to look at the quality of life of athletes that have experienced concussion.

If any of the questions have made you feel upset or worried please contact the researcher. If you are concerned about how you're currently coping there are also places that you can call and people you can talk to:

Immediate Support: Due to the sensitive nature of the research and the topics that have arisen, below are some options to consider if you feel distressed or would like some further information.

- https://www.mind.org.uk/
- https://www.samaritans.org/how-we-can-help-you/contact-us (Tel: 116 123)
- https://www.braininjurygroup.co.uk/brain-injury-group-directory/charities-support-groups/
- https://www.thedtgroup.org/brain-injury/

If you are a student, you are advised to contact your University's student services if you are feeling distressed.

Useful Readings:

- NHS Concussion information - https://www.nhs.uk/conditions/Concussion/

Dissemination of Results: Participants will only be informed of the findings upon completion of the study. If you are interested in the results of the study, you are invited to contact the researcher Daniel Walker (walkerd@edgehill.ac.uk) on completion of the project in September 2022. The researcher will then be happy to email a summary of the main findings and what they mean.

Reminder: There is also the opportunity to take part a second time, 6 months after your first visit. This is to compare your results between the two different time points to see whether things have changed. If you wish to do so you can contact the researcher. Just because you have taken part in this one does not mean you have to take part again, likewise, providing your contact details for a second time does not mean you have to take part again. If you receive £16 for this study you will receive £24 for doing it again. If you receive course credits you have the option to select course credits again or £16.

Contact Details:

Lead Researcher*:* Daniel Walker (walkerd@edgehill.ac.uk)

Supervisors*:* Dr. Alex Balani (balanial@edgehill.ac.uk)
Dr. Adam Qureshi (qureshia@edgehill.ac.uk)
Dr. David Marchant (marchand@edgehill.ac.uk)

Chair of Departmental Ethics Committee: Dr. Andy Levy (levya@edgehill.ac.uk)

Participants are encouraged to contact the lead researcher with any queries they may have regarding the study, including withdrawal of data. Participants are reminded that they have until two weeks after their participation to contact the lead researcher, that is 23:59 14 days after taking part, regarding withdrawal of data. You will need your unique ID(Six-digit number. Two digits of your month of birth + last two digits of year of birth + first two digits of postcode) in order to do this. The researcher will then safely destroy your data and inform you by email when this has been done.

Appendix D – Participant Information Sheet

Are there misconceptions and poor attitudes towards concussion?

Background: A concussion is a temporary injury to the brain caused by a bump, blow or jolt to the head or body. In sport, you might have heard it called a "knock" or having your "bell rung". A concussion usually only lasts a few days or weeks, although it sometimes needs emergency treatment, and some people can have longer-lasting problems. Signs of concussion usually appear within a few minutes or hours after a head injury, but sometimes they can take a few days. Symptoms include loss of consciousness, headaches, dizziness, vomiting, confusion, memory loss, trouble balancing, mood swings and blurred vision.

Concussion is receiving more attention than ever in the sporting world and the media. However, there are still some people that may disagree with changes to sport and see head injury as part and parcel of the game. This study will attempt to uncover whether there are poor attitudes towards concussion in sport and whether people truly know the characteristics of one.

Eligibility Requirements:

In this study we need athletes that have sustained concussion in a sporting setting. If you think you had a concussion, it does not matter whether a doctor diagnosed it or not, a simple questionnaire during the study will measure this.

What do I need to do? If you are eligible and would like to participate, following providing informed consent you may proceed. This will involve an approximate 30-minute interview with the researcher.

Are there any risks to participating? We may touch on the negative consequences of concussion which could cause you some psychological discomfort or concern. You can stop the interview at any point if you wish to do so without giving reason.

Are there any benefits to participating? By taking part in this study, you are helping us gain a better understanding of potential misconceptions as to what concussion is, as well as any dangerous negative attitudes athletes may hold towards concussion. Also, many people are not aware of how serious concussion can be, and by taking part you are helping raise awareness of the dangers of concussion and how important it is to prevent it from happening in sport.

What will happen to the information I provide? All the data collected from you will be kept **anonymous** and **confidential.** Only the researchers will have access to the information you provide, and it will be for the purposes stated on this screen. Data from Qualtrics will be stored safely with limited access and will be password protected. Similarly, audio data collected from the interviews will be stored safely on the researchers' university Z drive in encrypted/password protected folders.

Note that you are free to withdraw from the study without having to give reason. This means that you do not have to take part and that you can stop at any time during the study.

If you wish to withdraw your data you are free to do so up until two weeks after you took part. The deadline for this will be at 23:59, 14 days after you took part, and you can do so by contacting the researcher by email (walkerd@edgehill.ac.uk), simply stating you wish to withdraw your data and providing your unique ID (Six-digit number. Two digits of month of birth + last two digits of year of birth + first two digits of postcode) used during the study. The researcher will inform you by email when your data has been destroyed. The researcher will keep a record of participants that have requested to withdraw their data, and this will again be safely stored on the researchers' university Z drive in encrypted/password protected folders

You are welcomed to contact the researcher if you have any questions before taking part in the study.

Lead Researcher: Daniel Walker (walkerd@edgehill.ac.uk)

Supervisors: Dr. Alex Balani (balanial@edgehill.ac.uk**)**
Dr. Adam Qureshi (qureshia@edgehill.ac.uk**)**
Dr. David Marchant (marchand@edgehill.ac.uk**)**

Chair of Departmental Ethics Committee: Dr. Andy Levy (levya@edgehill.ac.uk)

Appendix E – Participant Debrief Form

Are there misconceptions and poor attitudes towards concussion?

Firstly, thank you for taking part in this study.

Background: Research has shown that not only do athletes that have sustained multiple concussions become less likely to disclose whether they have had a concussion, for each one they have, but also that increased concussion history also does not increase concussion knowledge (Register-Mihalik et al., 2017). Therefore, this study aims to investigate attitudes that athletes that have had concussion have about this type of head injury, as well as assessing their knowledge of what they are. The interview questions were designed to investigate these two factors by asking not only about your own views but how your teammates and coaches would react too. It is predicted that athletes may possess unhealthy attitudes towards concussion, and varying knowledge of what they are.

If any of the questions have made you feel upset or worried, please contact the researcher. If you are concerned about how you're currently coping there are also places that you can call and people you can talk to:

Immediate Support: Due to the sensitive nature of the research and the topics that have arisen, below are some options to consider if you feel distressed or would like some further information.

- https://www.mind.org.uk/
- https://www.samaritans.org/how-we-can-help-you/contact-us (Tel: 116 123)
- https://www.braininjurygroup.co.uk/brain-injury-group-directory/charities-support-groups/
- https://www.thedtgroup.org/brain-injury/

If you are a student, you are advised to contact your University's student services if you are feeling distressed.

Useful Readings:

- NHS Concussion information - https://www.nhs.uk/conditions/Concussion/

Dissemination of Results: Participants will only be informed of the findings upon completion of the study. If you are interested in the results of the study, you are invited to contact the researcher Daniel Walker (walkerd@edgehill.ac.uk) on completion of the project in September 2022. The researcher will then be happy to email a summary of the main findings and what they mean.

Contact Details:

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Participants are encouraged to contact the lead researcher with any queries they may have regarding the study, including withdrawal of data. Participants are reminded that they have until two weeks after their participation to contact the lead researcher, that is 23:59 14 days after taking part, regarding withdrawal of data. You will need your unique ID(Six-digit number. Two digits of your month of birth + last two digits of year of birth + first two digits of postcode) in order to do this. The researcher will then safely destroy your data and inform you by email when this has been done.

Appendix F – Participant Information Sheet

Developing a new pain scale

Background: Physical pain can have a negative impact on both mood (Travaglini et al., 2020) and our quality of life (Waldfogel et al., 2017). Increased levels of physical pain can have a worse effect on these outcomes and therefore it is important to know how much pain people are in, whether that is from an injury sustained competing in sport or in the workplace or persistent pain like rheumatism or cancer. To date, the most used pain scale simply asks how much pain people have experienced in the past week from 0-10. This study attempts to validate a new measure of pain that attempts to capture pain over different periods of time as well as identifying areas of pain that may lead to poorer mental health and lower quality of life.

Eligibility Requirements: In this study we require people that are currently in pain and those that are not to validate the areas of pain that may have an effect on mental health and quality of life.

Exclusion criteria: If you are under the age of 18 you cannot take part in this study.

What do I need to do? If you are eligible and want to take part, following providing informed consent you may proceed. This will involve taking part in a series of questionnaires that will ask you to report your physical pain symptoms. The survey will take approximately 10-15 minutes to complete.

Are there any risks to participating? There are no known risks to participating in this study.

Are there any benefits to participating? By taking part in this study, you are helping us gain a better understanding of the role that pain can play on mood and quality of life, and perhaps a better way of assessing this.

What will happen to the information I provide? All the data collected from you will be kept **confidential.** Only the researchers will have access to the information you provide, and it will be for the purposes stated on this screen. Data from the questionnaires will be stored safely in Qualtrics with limited access and will be password protected.

If you wish to withdraw your data you are free to do so up until two weeks after you took part. The deadline for this will be at 23:59, 14 days after you took part, and you can do so by contacting the researcher by email (walkerd@edgehill.ac.uk), simply stating you wish to withdraw your data and providing your unique ID (Six-digit number. Two digits of month of birth + last two digits of year of birth + first two digits of postcode) used during the study. The researcher will inform you by email when your data has been destroyed. The researcher will keep a record of participants that have requested to withdraw their data, and this will again be safely stored on the researchers' university Z drive in encrypted/password protected folders.

Lead Researcher: Daniel Walker (walkerd@edgehill.ac.uk)

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Chair of Departmental Ethics Committee: Dr. Lars McNaughton (mcnaughl@edgehill.ac.uk)

Appendix G – Participant Debrief Form

Developing a new pain scale

Firstly, thank you for taking part in this study.

Background: Research has shown a link between pain and depression (Ishak et al., 2018) and this may negatively impact quality of life. This study aims to provide a new way assessing physical pain among people that are experiencing pain. At present the NRS-11 is widely utilised where participants report between 0-10 on how much pain they have experienced in the past week. Visual Analog Scales are sometimes used where participants place a marker on a line to indicate how much pain they are feeling. McGill's Pain Questionnaire attempts to understand the feeling of the pain they are experiencing by asking participants to report what words best describes their pain, involving 78 different descriptors. Our pain scale will attempt to record the areas of physical pain that participants are experiencing and whether some areas of pain are worse for mental health and quality of life. Additionally, this scale asks about your physical pain at present and in the past week to get a better understanding of how this is perceived.

Reminder: Participants are encouraged to contact the lead researcher with any queries they may have regarding the study, including withdrawal of data. Participants are reminded that they have until two weeks after their participation to contact the lead researcher, that is 23:59 14 days after taking part, regarding withdrawal of data. You will need your unique ID(Six-digit number. Two digits of your month of birth + last two digits of year of birth + first two digits of postcode) to do this. The researcher will then safely destroy your data and inform you by email when this has been done.

Lead Researcher*:* Daniel Walker (walkerd@edgehill.ac.uk)

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Appendix H – Post-Concussion Symptom Scale

Post Concussion Symptom Scale

Please report the severity of symptoms in the 24 hours after suspected concussion.

No symptoms "0" --- Moderate "3" --- Severe "6"

	0	1	2	3	4	5	6
Headache	○	○	○	○	○	○	○
Nausea	○	○	○	○	○	○	○
Vomiting	○	○	○	○	○	○	○
Balance problems	○	○	○	○	○	○	○
Dizziness	○	○	○	○	○	○	○
Fatigue	○	○	○	○	○	○	○
Trouble falling to sleep	○	○	○	○	○	○	○
Excessive sleep	○	○	○	○	○	○	○
Loss of sleep	○	○	○	○	○	○	○
Drowsiness	○	○	○	○	○	○	○
Light sensitivity	○	○	○	○	○	○	○
Noise sensitivity	○	○	○	○	○	○	○
Irritability	○	○	○	○	○	○	○
Sadness	○	○	○	○	○	○	○
Nervousness	○	○	○	○	○	○	○
More emotional	○	○	○	○	○	○	○
Numbness	○	○	○	○	○	○	○
Feeling "slow"	○	○	○	○	○	○	○
Feeling "foggy"	○	○	○	○	○	○	○
Difficulty concentrating	○	○	○	○	○	○	○
Difficulty remembering	○	○	○	○	○	○	○
Visual problems	○	○	○	○	○	○	○

Appendix I – Center for Epidemiological Studies Depression Scale

Center for Epidemiologic Studies Depression Scale (CESD)

Instructions: Below is a list of the ways you might have felt or behaved. Please state how often you have felt this way **during the past week.**

	Rarely or none of the time (less than 1 day)	Some or a little of the time (1-2 days)	Occasionally or a moderate amount of time (3-4 days)	Most or all of the time (5-7 days)
I was bothered by things that usually don't bother me.	○	○	○	○
I did not feel like eating; my appetite was poor.	○	○	○	○
I felt that I could not shake off the blues even with help from my family or friends.	○	○	○	○
I felt I was just as good as other people.	○	○	○	○
I had trouble keeping my mind on what I was doing.	○	○	○	○
I felt depressed.	○	○	○	○
I felt that everything I did was an effort.	○	○	○	○
I felt hopeful about the future.	○	○	○	○
I thought my life had been a failure.	○	○	○	○
I felt fearful.	○	○	○	○
My sleep was restless.	○	○	○	○
I was happy.	○	○	○	○
I talked less than usual.	○	○	○	○
I felt lonely.	○	○	○	○
People were unfriendly.	○	○	○	○
I enjoyed life.	○	○	○	○
I had crying spells.	○	○	○	○
I felt sad.	○	○	○	○
I felt that people disliked me.	○	○	○	○
I could not "get going."	○	○	○	○

Appendix J – The State-Trait Anxiety Inventory

State-Trait Anxiety Inventory Y-1

Directions: Read each statement and select the appropriate option that indicates how you feel *right now*, that is, *at this moment*.

	Not at all	Somewhat	Moderately so	Very much so
I feel calm	○	○	○	○
I feel secure	○	○	○	○
I am tense	○	○	○	○
I feel strained	○	○	○	○
I feel at ease	○	○	○	○
I feel upset	○	○	○	○
I am presently worrying over possible misfortunes	○	○	○	○
I feel satisfied	○	○	○	○
I feel frightened	○	○	○	○
I feel comfortable	○	○	○	○
I feel self-confident	○	○	○	○
I feel nervous	○	○	○	○
I am jittery	○	○	○	○
I feel indecisive	○	○	○	○
I am relaxed	○	○	○	○
I feel content	○	○	○	○
I am worried	○	○	○	○
I feel confused	○	○	○	○
I feel steady	○	○	○	○
I feel pleasant	○	○	○	○

State-Trait Anxiety Inventory Y-2

Directions: Read each statement and select the appropriate option that indicates how you *generally feel*.

	Almost never	Sometimes	Often	Almost always
I feel pleasant	○	○	○	○
I feel nervous and restless	○	○	○	○
I feel satisfied with myself	○	○	○	○
I wish I could be as happy as others seem to be	○	○	○	○
I feel like a failure	○	○	○	○
I feel rested	○	○	○	○
I am "calm, cool, and collected"	○	○	○	○
I feel that difficulties are piling up so that I cannot overcome them	○	○	○	○
I worry too much over something that really doesn't matter	○	○	○	○
I am happy	○	○	○	○
I have disturbing thoughts	○	○	○	○
I lack self-confidence	○	○	○	○
I feel secure	○	○	○	○
I make decisions easily	○	○	○	○
I feel inadequate	○	○	○	○
I am content	○	○	○	○
Some unimportant thought run through my mind and bothers me	○	○	○	○
I take disappointments so keenly that I can't put them out of my mind	○	○	○	○
I am a steady person	○	○	○	○
I get in a state of tension or turmoil as I think over my recent concerns and interests	○	○	○	○

Appendix K – Positive And Negative Affect Scale

Positive And Negative Affect Scale (PANAS-SF)

Indicate the extent you have felt this way **over the past week.**

	Very slightly or not at all	A little	Moderately	Quite a bit	Extremely
Interested	○	○	○	○	○
Distressed	○	○	○	○	○
Excited	○	○	○	○	○
Upset	○	○	○	○	○
Strong	○	○	○	○	○
Guilty	○	○	○	○	○
Scared	○	○	○	○	○
Hostile	○	○	○	○	○
Enthusiastic	○	○	○	○	○
Proud	○	○	○	○	○
Irritable	○	○	○	○	○
Alert	○	○	○	○	○
Ashamed	○	○	○	○	○
Inspired	○	○	○	○	○
Nervous	○	○	○	○	○
Determined	○	○	○	○	○
Attentive	○	○	○	○	○
Jittery	○	○	○	○	○
Active	○	○	○	○	○
Afraid	○	○	○	○	○

Appendix L – Royal Prince Alfred Prospective Memory Test

RPA-ProMem
Royal Prince Alfred Prospective Memory Test

FORM 1

ID__________
Date_________

Instructions: "As I mentioned before, today we will be doing some tasks to test certain areas such as your memory and attention. Firstly, I am going to ask you to remember to do some things at a later stage of the assessment. You can use any techniques that you think might help you remember these things."

START TIME: ___________________________

Part 1 and Part 2

"I am going to leave this clock here where you can see it. **In 15 minutes time**, I would like you to tell me it's time for a coffee break. Do this as close to 15 minutes' time as you can. The other thing I would like you to do, **at the end of our session** today, is to ask me for an information sheet on note-taking strategies." *(Place digital clock in subject's direct view).*

- *Verify encoding of instructions and repeat if necessary*

Part 1 (Short-term, Time-based)

SUBJECT'S RESPONSE: ____

____ TIME: _________________________

Part 2 (Short-term, Event-based)

TIME OF TARGET EVENT: ____________________ *(i.e., time session ends; time alarm or phone rings)*

SUBJECT'S RESPONSE: ____

____ TIME: _________________________

Part 3 and Part 4

Instructions [administered at end of session]: "I am going to ask you to do some more things after we are finished today. You can use any method that will help you to remember to do the things I ask you to do. It is important that you try your best to remember".

"Firstly, when you arrive home today, I want you to phone and leave a message on my voice mail, telling me **what the weather is like**. The number is [*insert appropriate #*]. The second thing I would like you to do this week is to return this postcard to me on [date to be posted, one week from now] with your name and the word **HAWAII** written on the postcard. Will you be able to do this on that day? *[If not, plan another day]" (Make sure it is already stamped, addressed and labelled with participant ID code).*

- *Verify encoding of instructions and repeat if necessary*

Part 3 (Long-term, Event-based)

TIME OF TARGET EVENT: ____________________ *(i.e., approximate time expected to return home)*

SUBJECT'S RESPONSE: ____

____ TIME: _________________________

Part 4 (Long-term, Time-based)

TIME OF TARGET EVENT: ____________________ *(i.e., date one week from assessment session)*

SUBJECT'S RESPONSE: ____

____ DATE: _________________________

Comments:

Appendix M – Wechsler Memory Scale III – Verbal Paired Associates I/II

4. Verbal Paired Associates I

TIME LIMIT:
Read one pair of words every 3 seconds. Pause 5 seconds after reading each list and before presenting recall. During recall, provide correct response if examinee does not respond within 5 seconds.

RECORDING:
Place a tick (✔) for each correct association. Write incorrect responses verbatim.

SCORING RULE:
0–1 pt. for each item

List A	Recall A/Response	Score 0 or 1
Truck–Arrow	1. Bank (Cartoon)	
Insect–Acorn	2. Reptile (Clown)	
Reptile–Clown	3. Star (Ladder)	
Bank–Cartoon	4. Rose (Bag)	
Star–Ladder	5. Elephant (Glass)	
Badger–Paper	6. Truck (Arrow)	
Rose–Bag	7. Insect (Acorn)	
Elephant–Glass	8. Badger (Paper)	

List A Recall Range = 0 to 8

1st Recall Total Score Range = 0 to 8

List B	Recall B/Response	Score 0 or 1
Star–Ladder	1. Elephant (Glass)	
Elephant–Glass	2. Insect (Acorn)	
Insect–Acorn	3. Reptile (Clown)	
Truck–Arrow	4. Rose (Bag)	
Reptile–Clown	5. Star (Ladder)	
Bank–Cartoon	6. Badger (Paper)	
Badger–Paper	7. Bank (Cartoon)	
Rose–Bag	8. Truck (Arrow)	

List B Recall Range = 0 to 8

List C	Recall C/Response	Score 0 or 1
Rose–Bag	1. Insect (Acorn)	
Badger–Paper	2. Star (Ladder)	
Star–Ladder	3. Truck (Arrow)	
Reptile–Clown	4. Rose (Bag)	
Elephant–Glass	5. Elephant (Glass)	
Insect–Acorn	6. Reptile (Clown)	
Bank–Cartoon	7. Bank (Cartoon)	
Truck–Arrow	8. Badger (Paper)	

List C Recall Range = 0 to 8

List D	Recall D/Response	Score 0 or 1
Badger–Paper	1. Star (Ladder)	
Truck–Arrow	2. Rose (Bag)	
Star–Ladder	3. Insect (Acorn)	
Insect–Acorn	4. Badger (Paper)	
Rose–Bag	5. Elephant (Glass)	
Reptile–Clown	6. Bank (Cartoon)	
Bank–Cartoon	7. Reptile (Clown)	
Elephant–Glass	8. Truck (Arrow)	

List D Recall Range = 0 to 8

Recall Total Score Range = 0 to 32

(Sum Lists A–D Recall Score

Learning Slope Calculation

[ ] – [ ] = [ ] Learning Slope Range = -8 to +8

List D Recall Range = 0 to 8 — List A Recall Range = 0 to 8

14. Verbal Paired Associates II

Recall

ADMINISTER 25–35 MINUTES AFTER VERBAL PAIRED ASSOCIATES I.

RECORDING:
Place a tick (✔) for each correct association. Write incorrect responses verbatim.

SCORING RULE:
0–1 pt. for each item

Recall	Response	Score 0 or 1
1. **Truck** (Arrow)		
2. **Insect** (Acorn)		
3. **Reptile** (Clown)		
4. **Bank** (Cartoon)		
5. **Star** (Ladder)		
6. **Badger** (Paper)		
7. **Rose** (Bag)		
8. **Elephant** (Glass)		

Recall Total Score Range = 0 to 8 [ ]

Percent Retention Calculation

[ ] ÷ [ ] × 100 = [ ] Percent Retention Range = 0 to 100%

VPA II Recall Total Score Range = 0 to 8; VPA I List D Recall Range = 0 to 8

Recognition

RECORDING:
Circle Y or N.

SCORING RULE:
0–1 pt. for each item

Item	Circle Y or N	Score 0 or 1
1. Rose-Bag	***Y*** N	
2. Queen-Thumb	Y ***N***	
3. Elephant-Glass	***Y*** N	
4. Football-Forest	Y ***N***	
5. Star-Ladder	***Y*** N	
6. Badger-Paper	***Y*** N	
7. Dish-Corner	Y ***N***	
8. Perfume-Monkey	Y ***N***	
9. Truck-Arrow	***Y*** N	
10. Dance-Rocket	Y ***N***	
11. Peanut-Pencil	Y ***N***	
12. Bank-Cartoon	***Y*** N	
13. Insect-Acorn	***Y*** N	
14. Pocket-Ribbon	Y ***N***	
15. Sweet-Typewriter	Y ***N***	
16. Reptile-Clown	***Y*** N	
17. Wrinkle-Termite	Y ***N***	
18. Rose-Bag	***Y*** N	
19. Chicken-Submarine	Y ***N***	
20. Star-Ladder	***Y*** N	
21. Rain-Circus	Y ***N***	
22. Bread-Island	Y ***N***	
23. Elephant-Glass	***Y*** N	
24. Insect-Acorn	***Y*** N	

[ ] Recognition Total Score Range = 0 to 24

Percent Retention Calculation (Faces II)

[ ] ÷ [ ] × 100 = [ ] Percent Retention Range = 0 to 100%

Faces II Recognition TS Range = 0 to 48; Faces I Recognition TS Range = 0 to 48

Appendix N – Athlete Life Quality Scale

Athlete Life Quality Scale

Using the scale below, indicate how satisfied you are with the various aspects of your life listed.

	Very dissatisfied	Dissatisfied	Slightly dissatisfied	Neutral/Undecided	Slightly satisfied	Satisfied	Extremely Satisfied
Your own physical health	○	○	○	○	○	○	○
The amount of free/recovery time you have away from sport	○	○	○	○	○	○	○
Your relationships with family members	○	○	○	○	○	○	○
Your relationships with friends	○	○	○	○	○	○	○
Your social life	○	○	○	○	○	○	○
Your relationships with your coaches	○	○	○	○	○	○	○
Your relationships with your teammates	○	○	○	○	○	○	○
Your level of physical condition	○	○	○	○	○	○	○
Your athletic performance	○	○	○	○	○	○	○
Your role on your team	○	○	○	○	○	○	○
Your financial situation	○	○	○	○	○	○	○
Your spiritual health	○	○	○	○	○	○	○
Your mental health	○	○	○	○	○	○	○
Your relationship with your boyfriend/girlfriend, spouse, etc.	○	○	○	○	○	○	○
Your life as a whole	○	○	○	○	○	○	○

Appendix O – Health Related Quality of Life: SF-12

Q72

Health Related Quality of Life Short - Form 12

Q73

In general would you say your health is:

- ○ Excellent
- ○ Very good
- ○ Good
- ○ Fair
- ○ Poor

---------- Page Break ----------

Q74

The following two questions are about how activities you might do during a typical day. Does YOUR HEALTH NOW LIMIT YOU in these activities? If so, how much?

Q75

MODERATE ACTIVITIES, such as moving a table, pushing a vacuum cleaner, bowling, or playing golf:

- ○ Yes, limited a lot
- ○ Yes, limited a little
- ○ No, not limited at all

Q76

Climbing SEVERAL flights of stairs:

- Yes, limited a lot
- Yes, limited a little
- No, not limited at all

---------- Page Break ----------

Q77

During the PAST 4 WEEKS have you had any of the following problems with your work or other regular activities AS A RESULT OF YOUR PHYSICAL HEALTH?

Q78

ACCOMPLISHED LESS than you would like:

- Yes
- No

Q79

Were limited in the KIND of work or other activities

- Yes
- No

Q80

During the PAST 4 WEEKS, were you limited in the kind of work you do or other regular activities AS A RESULT OF ANY EMOTIONAL PROBLEMS (such as feeling depressed or anxious)?

Q81

ACCOMPLISHED LESS than you would like:

- ○ Yes
- ○ No

Q82

Didn't do work or other activities as CAREFULLY as usual:

- ○ Yes
- ○ No

-- Page Break ---

Q83

During the PAST 4 WEEKS, how much did PAIN interfere with your normal work (including both work outside the home and housework)?

- ○ Not at all
- ○ A little bit
- ○ Moderately
- ○ Quite a bit
- ○ Extremely

Q84

The next three questions are about how you feel and how things have been DURING THE PAST 4 WEEKS. For each question, please give the one answer that comes closest to the way you have been feeling. How much of the time during the PAST 4 WEEKS -

	All of the time	Most of the time	A good bit of the time	Some of the time	A little of the time	None of the time
Have you felt calm and peaceful?	○	○	○	○	○	○
Did you have a lot of energy?	○	○	○	○	○	○
Have you felt downhearted and blue?	○	○	○	○	○	○

Page Break

Q85

During the PAST 4 WEEKS, how much of the time has your PHYSICAL HEALTH OR EMOTIONAL PROBLEMS interfered with your social activities (like visiting with friends, relatives, etc.)?

- ○ All of the time
- ○ Most of the time
- ○ A good bit of the time
- ○ Some of the time
- ○ A little of the time
- ○ None of the time

Appendix P – Descriptive statistics of measures of mental health, cognitive ability, and quality of life.

	T1 (*n* = 43)	T2 (*n* = 13)	Change
	M (SD) [Mdn]	*M (SD) [Mdn]*	*M (SD) [Mdn]*
Depressive Symptoms	18.30 (11.57)	20.15 (11.11)	1.85 (-0.46)
State-Anxiety Symptoms	39.56 (13.56)	36.54 (13.16)	-3.02 (-0.40)
Trait-Anxiety Symptoms	45.49 (13.53)	45.69 (13.24)	0.20 (-0.29)
PANAS Positive Scores	30.35 (6.89)	29.31 (6.76)	-1.04 (-0.13)
PANAS Negative Scores	20.93 (8.74)	18.92 (6.45)	-2.01 (-2.29)
Quality of Life Total Scores	24.00 (6.30)	22.77 (5.75)	-1.23 (-0.55)
Quality of Life Physical Scores	8.65 (2.15)	7.77 (1.83	-0.88 (-0.32)
Quality of Life Mental Scores	9.79 (3.37)	9.92 (3.04)	0.13 (-0.33)
N-Back			
One-Back			
Target Accuracy (%)	89.07 (12.11)	91.54 (11.44)	2.47 (-0.67)
Target RT (S)	0.58 (0.16)	0.62 (0.15)	0.04 (-0.01)
Non-Target Accuracy (%)	94.77 (4.08)	97.69 (3.30)	2.92 (-0.78)
Non-Target RT (S)	0.63 (0.17)	0.60 (0.12)	-0.03 (-0.05)
Two-Back			
Target Accuracy (%)	83.49 (17.44)	90.00 (13.54)	6.51 (-3.90)
Target RT (S)	0.70 (0.26)	0.61 (0.20)	-0.09 (-0.06)
Non-Target Accuracy (%)	91.98 (8.03)	96.15 (8.45)	4.17 (0.42)
Non-Target RT (S)	0.71 (0.28)	0.70 (0.22)	-0.01 (-0.06)
Three-Back			
Target Accuracy (%)	70.47 (23.50)	79.23 (21.78)	8.76 (-1.72)
Target RT (S)	0.90 (0.32)	0.90 (0.24)	-(-0.08)
Non-Target Accuracy (%)	87.56 (13.95)	93.46 (8.26)	5.90 (-5.69)
Non-Target RT (S)	0.82 (0.26)	0.81 (0.21)	-0.01 (-0.05)
Local-Global			
Local Stimuli Accuracy (%)	75.88 (12.93)	76.23 (26.36)	0.35 (13.43)
Local Stimuli RT (S)	0.54 (0.18)	0.46 (0.20)	-0.08 (0.02)
Global Stimuli Accuracy (%)	89.05 (10.69)	95.62 (5.12)	6.57 (-5.57)
Global Stimuli RT (S)	0.43 (0.14)	0.36 (0.64)	-0.07 (0.50)
Digit-Span Forwards			
Accuracy (%)	57.77 (14.79)	60.85 (16.32)	3.08 (1.53)
RT (S)	5.27 (1.30)	5.02 (1.22)	-0.25 (-0.08)
Stop-Signal			
Go Trials Accuracy (%)	96.00 (10.33)	93.31 (18.19)	-2.69 (7.86)
Go Trials RT (S)	0.84 (0.24)	0.90 (0.33)	0.06 (0.09)
Stop Trials Accuracy (%)	65.53 (22.45)	71.23 (26.85)	5.70 (4.40)
Stop Trials RT (S)	0.65 (0.28)	0.60 (0.38)	-0.05 (0.10)
Digit-Span Backwards			
Accuracy (%)	41.56 (15.25)	48.85 (21.39)	7.29 (6.14)
RT (S)	8.91 (3.94)	7.88 (2.19)	-1.03 (-1.75)
Colour Stroop Test			
Congruent Accuracy (%)	98.49 (1.87)	98.92 (1.32)	0.43 (-0.55)
Congruent RT (S)	0.76 (0.17)	0.68 (0.11)	-0.08 (-0.06)
Incongruent Accuracy (%)	92.67 (5.98)	93.08 (3.15)	0.41 (-2.83)
Incongruent RT (S)	0.91 (0.22)	0.83 (0.17)	-0.08 (-0.05)
TMT			
TMT (A) Accuracy (%)	95.16 [100.00]	89.23 [100.00]	-5.93
TMT (A) RT (S)	50.10 [37.94]	31.40 [30.20]	-18.70
TMT (B) Accuracy (%)	96.40 [100.00]	86.38 [96.00]	-10.02
TMT (B) RT (S)	51.65 [48.48]	38.42 [37.09]	-13.23
TMT Accuracy Difference (%)	1.23 (8.23)	-2.85 (16.47)	-4.08
TMT RT Difference (S)	1.55 (30.96)	7.02 (7.32)	5.47
Corsi Block Test			
Corsi Block Load	6.02 (1.14)	6.31 (1.55)	0.29 (0.41)
Prospective Memory Test			
Short-Term Memory			
Time*	0.28 (0.45)	0.38 (0.51)	0.10 (0.06)

Event*	0.93 (0.26)	0.92 (0.28)	-0.01 (0.02)
Long-Term Memory			
Time*	0.30 (0.46)	0.15 (0.38)	-0.15 (-0.08
Event*	0.67 (0.47)	0.38 (0.51)	-0.29 (0.04)
Verbal Paired Associates I/II			
I Recall	22.00 (5.02)	26.31 (2.75)	4.31 (-2.27)
II Recall (%)	98.42 (5.40)	96.15 (10.69)	-2.27 (5.29)

*- Scored as, 0 = incorrect, 1 = correct

Appendix Q - Table depicting the frequencies of predominant sports

Predominant Sport	*N*	Total sample (%)	Sport sample (%)
Rugby	43	29.9	61.4
Athletics	6	4.2	8.6
Football	5	3.5	7.1
Netball	2	1.4	2.9
Touch Rugby	2	1.4	2.9
Baseball	1	.7	1.4
Weightlifting	1	.7	1.4
Handball	1	.7	1.4
Squash	1	.7	1.4
Equestrian	1	.7	1.4
Skiing	1	.7	1.4
Cycling	1	.7	1.4
Badminton	1	.7	1.4
Boxing	1	.7	1.4
Cricket	1	.7	1.4
Dance	1	.7	1.4
Taekwondo	1	.7	1.4
Total	70	48.6	100

Appendix R - Table depicting number of SRC's sustained by sport-type and non-sport

	Number of SRC's												
	1	2	3	4	5	6	7	8	9	10	11	12	Total
Contact Sport													
Rugby	9	9	6	4	6	4	-	1	-	1	1	1	156
Football	2	-	-	1	-	-	-	-	-	-	-	-	6
Skiing	1	-	-	-	-	-	-	-	-	-	-	-	1
Boxing	1	-	-	-	-	-	-	-	-	-	-	-	1
Taekwondo	-	-	-	-	-	-	-	-	-	-	-	-	0
Total	13	9	6	5	6	4	-	1	-	1	1	1	**164**
Non-Contact Sport													
Athletics	1	-	-	-	-	-	-	-	-	-	-	-	1
Netball	-	-	-	-	-	-	-	-	-	-	-	-	0
Squash	-	-	-	-	-	-	-	-	-	-	-	-	0
Touch Rugby	-	-	1	-	-	1	-	-	-	-	-	-	9
Cricket	-	-	-	-	-	-	-	-	-	-	-	-	0
Equestrian	-	1	-	-	-	-	-	-	-	-	-	-	2
Baseball	-	-	-	-	-	-	-	-	-	1	-	-	10
Weightlifting	-	-	-	-	-	-	-	-	-	-	-	-	0
Handball	-	1	-	-	-	-	-	-	-	-	-	-	2
Cycling	-	1	-	-	-	-	-	-	-	-	-	-	2
Badminton	-	-	-	-	-	-	-	-	-	-	-	-	0
Dance	-	-	-	-	-	-	-	-	-	-	-	-	0
Total	1	3	1	-	-	1	-	-	-	1	-	-	**26**
Non-sport	3	-	1	1	1	-	-	1	-	1	-	-	**33**
Total	16	25	15	11	13	10	-	3	-	5	2	2	**223**

Appendix S – Semi-structured interview script

Interview Script Draft

Intro

Firstly, welcome to this study, thanks for agreeing to take part. My name's Danny and today we'll be discussing some of the attitudes that people have about concussion. Before we start, I just want to reassure you that you don't have to take part and if you want to stop at any point just let me know, you don't have to give any reason for this. Also, the interview will be recorded for audio transcription purposes, and you will remain anonymous. So, should we get started?

Warm-up Questions

1. Ok, so before we start with concussion, can you tell me a little bit about your sporting history?
    a. When did you start playing?
    b. What sports you've played?
    c. What levels you've played at?
    d. What made you play the sports that you did?

2. Do you prefer team sports over individual sports?
    a. Why?

3. How competitive would you say you are?
    a. Can you give an example of the most competitive example you've had in sport?

4. Can you tell me about your experiences with concussion then?
    a. How many?
    b. When was the most recent?
    c. How long did it take to recover from each?
    d. What symptoms did you experience in each?

Research Question	**Themselves**	**Teammates, coaches (others)**
Are athletes well-educated on concussion?	Can you tell me everything you already know about concussion, and whether you have had any training or education on concussion? Can you tell me about how you feel towards the education you've received about concussion in sport? - Could you give an example? - Could you elaborate on *x*, *y*, *z*? - What do you mean by, *x*, *y*, *z*?	Have your teammates had more or less the same education you've had on concussion in sport? - Why have they had more/less than you? - Are there differences between the levels played at? - Why is this? Is concussion not the same at all levels of sport?

Are athletes interested in learning more about concussion?	What steps would you take to learn more about concussion? - There is research that suggests increased self-awareness can increase chance of injury (Andersen & Williams, 1988; Ivarsson et al., 2014), do you think it would be better for athletes to not know about concussion? - Can you elaborate? - Why/why not?	Do you think your teammates would attend a seminar to learn more about concussion in sport? - Why do you think this? - Have they attended anything like this in the past? - Have your coaches? - Would/have you?
Do athletes know the true dangers of concussion?	Do you ever think that concussion now could impact you in later life? - What are the concerns of those that are the closest to you? - Are they aware of long-term consequences of concussion? - Do real life cases of former sportspeople	How do your teammates feel about the consequences of concussion? - Do they have anyone close to them who has struggled with mental health since having concussion? - What would happen if you were to back out of a tackle/header/challenge

	suffering from poor mental health, dementia, Alzheimer's disease worry you?	etc. for wanting to protect your head? - How would they react if you were to avoid anything head-related until competitive matches? Abstain in training etc.
Would athletes continue playing with suspected concussion?	What do you think are the reasons why players might continue to play? - Have you ever continued with suspected concussion? - What were your reasons?	*Hugo Lloris prompted change in the premier league when he ignored medical advice and ran back onto the pitch to continue playing after sustaining concussion. Now, if you have sustained concussion you must be substituted.* Have you ever known anyone to continue to play after a concussion? - Why do you think this was?
What are athletes' opinions on the advised recovery	Do you think you would adhere to the recovery guidance you were given if you sustained concussion?	If you sustained concussion, would your teammates and coaches view this in the same

period following concussion?	- Did you the first time? - Tell me more about your recovery period. - Did you continue to train/go to work?	way as if you'd sustained a physical injury? - How did they view it last time you had concussion? - How would you view a teammate that has had one?

Appendix T - Localised Pain Scale (LPS)

Y-1 (Please report the level of physical pain you are experiencing **right now**)

0 = No Pain

1-2 = Mild Pain

3-4 = Moderate Pain

5-6 = Severe Pain

Items:

Y1.1 Headache

Y1.2 Arm/Shoulder Pain

Y1.3 Knee/Ankle Pain

Y1.4 Abdominal Pain

Y1.5 Chest Pain

Y1.6 Back Pain

Y1.7 Other Pain

Y1.8 Overall Pain

Y-2 (Please report the level of physical pain you are experiencing **in the past week**)

0 = No Pain

1-2 = Mild Pain

3-4 = Moderate Pain

5-6 = Severe Pain

Items:

Y2.1 Headache

Y2.2 Arm/Shoulder Pain

Y2.3 Knee/Ankle Pain

Y2.4 Abdominal Pain

Y2.5 Chest Pain

Y2.6 Back Pain

Y2.7 Other Pain

Y2.8 Overall Pain