The ABCS of Sport-related Concussion in Junior Rugby Union: An Analysis of Antecedents, Behaviours, Consequences, and Sociotechnical Systems

Amanda Clacy

University of the Sunshine Coast
Declaration

‘I hereby declare that this dissertation is my own work and does not incorporate any material previously published or written by another person, nor material which has been submitted previously for the purpose of assessment without proper acknowledgement. This dissertation is being submitted for assessment as the final contribution following a Doctor of Philosophy (Arts), higher degree by research program’.

Signed ....................................................                   Date 17/06/2016.....................
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Abstract

Participating in any contact sport comes with an obvious increased risk of injury. The aim of this project was to explore the possible individual differences that may pre-dispose junior (11-17 years old) rugby union players to both sustaining a sport-related concussion, as well as the characteristics and behaviours which may lead them to experience a longer recovery profile following injury. Using a biopsychosocial framework, this research comprised of four major studies; the antecedents which may predict concussion; the behaviours that may increase a player’s risk of sustaining a concussion; the cognitive and emotional consequences of concussion; and a systems analysis of how people within different roles prevent, identify, and treat sport-related concussion.

The main contributions of this research were, (a) the factors which may potentially place a young athlete at risk of sustaining a sport-related concussion, and experiencing ongoing complications, were a complex interaction of largely unpredictable intrinsic and extrinsic variables; (b) training frequency and behaviour can predict concussion incidence in junior rugby, specifically unsupervised activity and safety behaviours; (c) concussion history was not significantly associated with current cognitive or emotional functioning in adolescents; and (d) despite the overlap across the rugby union system regarding how concussion is identified, there was minimal confidence in how concussion can be prevented as well as considerable inter-role inconsistencies in how concussion is treated and managed. Although this study was limited by its cross-sectional design and small sample size, it provides a comprehensive, robust methodology that may help inform future replications of the study.

Concussive injury may never be completely eliminated from rugby and other contact sports however by taking a multifaceted approach to better understanding the interaction between individual intrinsic and extrinsic variables - with consideration for the system in which they interact - may modulate the incidence of concussion in junior sport.
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Chapter One – Concussion in Sport

The first chapter in this thesis will provide a review of concussion in sport, including how it is defined and identified as well as summarising some of the current challenges in concussion research. Sport-related concussion is a multi-faceted issue, as such it is important to understand what is and some of the issues that have limited previous research before the studies within this thesis are presented.

Identifying Sport-Related Concussion

Concussion and the possible cumulative and enduring impacts of concussive injuries on brain function has become a topical concern, especially within the sporting community. While there is no universally accepted definition of concussion, there continues to be an alarming number of concussive injuries reported in contact sport. For example, in a population of Australian community rugby players (ranging from 15 to 45 years of age), Hollis et al. (2009) found that approximately 10% of players sustained at least one concussion per season, which equated to almost eight concussions per 1000 hours of participation. Despite growing public awareness of the severity of the issue, there is still a considerable lack of knowledge regarding not only the consequences of concussion on brain function, but also which factors may increase an individual’s likelihood of sustaining a concussion while participating in sport, and suffering more adverse effects of concussive injuries.

Concussion results from a forceful acceleration and/or deceleration of the brain induced by biomechanical forces, which results in the rapid onset of cognitive disruption and may or may not involve a loss of consciousness (LOC; Aubry et al., 2002; McCrory et al., 2013). Two modes of impact can lead to concussive injuries: impact loading, which occurs when the total applied force passes through the centre of gravity of the head following the rapid contact of solid objects (i.e., blunt impact with an object or the ground); and impulsive
loading, which is produced by parallel and oppositely directed forces in which effects to the head and neck are generated by inertia (e.g., whiplash; Ommaya, Goldsmith, & Thibault, 2002). While concussion is usually associated with blunt trauma to the head, research has found that impulsive loading produces concussion and concussive symptoms more effectively than blunt impact alone (Ommaya, Goldsmith, & Thibault, 2002). The brain is not a solid construct, rather it is a complex of tissue permeated by vascular structures surrounded by cerebro-spinal fluid; as such, it exhibits many aspects of fluid-like behaviour with force (Ommaya, Goldsmith, & Thibault, 2002). Following impact loading, neural pressure is produced in the direction of motion relative to the force of the blow which, with enough pressure, can lead to indentation and bruising, impact fractures, or mild traumatic brain injury (mTBI). Furthermore, translation of the force often produces a ‘wave effect’, leading to damage in regions of the brain not necessarily in direct contact with the point of impact (Ommaya, Goldsmith, & Thibault, 2002). Impulse loading, on the other hand, causes adjoining layers of the brain to shift in accordance to the translational velocity of the impact increasing outwardly relative to the axis of rotation, which typically originates from the neck. This sheer strain of underlying neural elements is the cause of injuries such as diffuse axonal injury, ruptured vessels, and subdural haematomas (Ommaya, Goldsmith, & Thibault, 2002).

In most real world incidences of head trauma it is possible for both translation and rotation force to be simultaneously present, such as during a scrum or tackle when the athlete may experience rapid deceleration at the same time as blunt head impact with the ground and/or other players, however each separate loading produces entirely different consequences. Kelly and Rosenberg (1997) presented three fundamental features in identifying concussion. These were (a) disturbance of vigilance with heightened distractibility; (b) inability to maintain a coherent stream of thought; and (c) inability to carry out a sequence of goal-directed movements. A number of physical, cognitive, and emotional
symptoms of concussion were proposed following the International Conference on Concussion in Sport (CIS) to help better identify concussion (see Table 1; Aubry et al., 2002; McCrory et al., 2005; 2009; 2013). One of the issues recurring in literature regarding the definition of concussion is whether it represents as a linear spectrum of injury severity, or whether different concussion subtypes exist (Aubry et al., 2002; McCrory et al., 2005; 2009; 2013). These subtypes of mTBI could represent variance in symptomology (e.g., confusion, memory loss, LOC); anatomical localisation (e.g., cerebral versus brainstem); genetic phenotype (i.e., apolipoprotein epsilon 4 (ApoE4) positive versus ApoE4 negative); neuropathological change (i.e., structural versus non-structural injury); or biochemical impact (i.e., rotational versus impact loading; Aubry et al., 2002; McCrory et al., 2005; 2009; 2013).

Table 1. Symptoms and Signs of Concussion

<table>
<thead>
<tr>
<th>Physical</th>
<th>Cognitive</th>
<th>Emotional</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>Headache</td>
<td>Loss of consciousness</td>
<td>Depression</td>
<td>Drowsiness</td>
</tr>
<tr>
<td>Dizziness</td>
<td>Loss of memory</td>
<td>Irritability</td>
<td>Insomnia</td>
</tr>
<tr>
<td>Blurred vision</td>
<td>Poor concentration</td>
<td>Unstable mood</td>
<td>Difficulty getting to/staying asleep</td>
</tr>
<tr>
<td>Photophobia</td>
<td>Disorientation</td>
<td>Aggressiveness</td>
<td>Uncharacteristic fatigue</td>
</tr>
<tr>
<td>Phonophobia</td>
<td>Feeling ‘foggy’</td>
<td>Nervousness</td>
<td></td>
</tr>
<tr>
<td>Nausea</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Numbness/tingling extremities</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vomiting</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Loss of balance</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note. Adapted from Aubry, M., Cantu, R., Dvorak, J., Graf-Baumann, T., et al. (2002); McCrory et al., 2005; 2009; 2013.

The Current Challenges in Concussion Research

The immediate response advice proposed in the concussion management guidelines developed by the CIS calls for the removal of athletes from play if a concussion is suspected (Aubry et al., 2002; McCrory et al., 2005; 2009; 2013). Furthermore, Rugby union Australia (ARU; 2014) along with the International Rugby Board (IRB; 2014) propose a 3-week break
from participating in both training and competition following a head injury causing concussion, which is mandatory for players younger than 19 years old. The assessment and management of concussion in rugby is complicated by suspected under-reporting of symptoms by athletes. Indeed, although most athletes acknowledge receiving formal education about the risks of concussion and management guidelines, 20% to 60% of athletes who suspected they may have had a concussion failed to report it to their coach, medic, or parent (Chrisman, Quitiquit, & Rivara, 2012; McCrea, Hammeke, Olsen, Leo, & Guskiewicz, 2004; Sye, Sullivan, & McCrory, 2006; Torres et al., 2013). In a qualitative focus-group study, Chrisman and colleagues (2012) found that although 60% of rugby players ($M = 17$ years; $SD = .96$) were able to identify the danger of concussion when presented with scenarios involving concussive symptoms (e.g., collided with another player and developed balance problems, headache, and felt ‘dazed’), they stated that they would continue to play. Similarly in an anonymous online survey of collegiate athletes, Torres et al. (2013) found that 43% of respondents who had a history of concussion reported that they had knowingly hidden symptoms of a concussion to avoid being removed from play, and 22% indicated that they would be unlikely to report concussion symptoms to a coach or athletic trainer in the future. This research illustrates that it is less a case of poor education or failure to identify a concussion and more likely players’ attitudes towards the seriousness of concussion at the time they occur and possibly not wanting to be removed from play (Chrisman, Quitiquit, & Rivara, 2012; McCrea et al., 2004; Torres et al., 2013).

The major challenge presented by under-reporting is in the sideline judgement of the severity of a head injury, especially when injured players may be intentionally withholding or ‘down playing’ their injuries. Sideline evaluation of cognitive function following a head knock is an essential component in the assessment of the injury and subsequent return-to-play decision (McCrory et al., 2013). For most sidelines measures of cognitive disruption (e.g.,
Sport Concussion Assessment Tool-Revised [SCAT2]) to be effective pre-injury functioning needs to be recorded, however baseline screening often beyond the resources of some sporting clubs (either due to cost or untrained personnel). This is particularly concerning in youth sport as younger athletes are maturing at a relatively rapid pace, requiring more frequent updates of their baseline measures compared with older athletes (Guskiewicz et al., 2004; McCrory, 2011; McCrory et al., 2013). Although it is noted that a ‘conservative’ return-to-play response is recommended for athletes under 18 years of age, the formal guidelines for the identification, prevention, and treatment of concussion do not differ for junior and adult athletes (Aubry et al., 2002; McCrory et al., 2005; 2009; 2013). As emphasised by Finch and colleagues (2013), this ‘one size fits all’ guidance for managing concussion fails to consider the broader contextual variables that may impact upon the underlying risk factors and epidemiology of sport-related concussion in a junior population. Younger athletes may also be less likely to have formally trained medical professionals knowledgeable about concussions available at sporting events; consequently there are considerable identification issues in youth sports (Cohen, Gioia, Atabaki, & Teach, 2009). While the initial cognitive impact of concussion may appear comparable for children and adults, the recovery profile and health consequences in children is largely unknown, as is the influence of pre-injury characteristics (e.g., physical fitness, personality, executive functioning) and injury details (e.g., magnitude and direction of impact, injury history) on long-term pathology.

This brief introduction to sport-related concussion highlights three important gaps and limitations in previous concussion research which will be addressed in this thesis. Firstly, underreporting and non-compliance have been found to be prevalent issues in sport-related concussion management possibly due to misunderstanding the seriousness of the injury although may also be an attempt at avoiding removal from participation. These are especially
issues in junior and community rugby clubs where there may not be the infrastructure or staffing to follow up every potential concussive injury that occurs. This leads to the second limitation in previous research. Sport-related concussion has received growing attention in research, medicine, and media however much of this attention has been directed towards adult and professional levels of sporting competition. Furthermore, and the third limitation to current research, is the strong research focus on factors in the immediate environment when concussion occurs (e.g., type and force of impact, use of protective gear such as headgear). Consequently, intrinsic, extrinsic, and sociotechnical factors have not been considered concurrently in sport-related concussion research. Given these gaps in literature, the focus of this thesis will be on junior levels of competition in community rugby. A robust methodology including biological and physical characteristics, self- and parent- reports, and consideration for contextual and sociotechnical factors will be utilised to better understand the ABCS of sport-related concussion in junior rugby.
Chapter Two - Considering the Adolescent Athlete

Adolescence is a developmental period associated with clear transitions in social roles (from dependent child to self-directed adult) interposed with a multitude of marked physical, hormonal, and cognitive changes. Perspectives on the development of the human brain have rapidly advanced throughout the past century. The age of puberty onset has been declining, with the early physical changes of puberty beginning in boys as young as 9 years old (Gluckman & Hanson, 2006), however the neurological developmental changes during this period have received less attention.

Neurological Development

The progressive hormonal and neuroanatomical changes occurring throughout puberty appear to create a ‘sensitive period’ of cognitive development in which the opportunity for disrupted development may have ongoing consequences. Early post-mortem studies such as those pioneered by Yakovlev and Lecours (1967) and Huttenlocher (1979) revealed that brain regions, especially the prefrontal cortex, continue to develop throughout childhood and into adolescence through two processes. Firstly, the myelination of axons in the prefrontal cortex and other association areas follows a chronological sequence that continues into young adulthood (Huttenlocher, 1979; Yurgelun-Todd, Killgore, & Young, 2002). Myelin acts as an insulator which increases the speed of inter-neuronal transmission of electrical impulses. Whereas sensory and motor brain regions become fully myelinated in the first few years of life, axons in the frontal cortex continue to be myelinated well into adolescence (Blakemore, 2012; Yakovlev & Lecours, 1967). Secondly, there is a proliferation of synapses (called synaptogenesis) in the prefrontal cortex during childhood and again at puberty, followed by a subsequent elimination (or ‘pruning’) and reorganisation of prefrontal synaptic connections throughout adolescence resulting in an overall decrease in synaptic density (Huttenlocher, 1979; Webb, Monk, & Nelson, 2001). Synaptic pruning is
necessary for the refinement of functional neural networks, leaving the remaining synaptic circuits more efficient. These two process of maturation culminate in an overall linear increase in cortical white matter as well as a region specific decrease in grey matter (Blakemore, 2012; Blakemore & Choudhury, 2006; Paus et al., 1999).

Developmental and prevention literature have both highlighted that consequent of the dramatic hormonal, cognitive, and neurological changes being experienced, children and adolescents appear to go through a stage of heightened susceptibility to addictive behaviours (e.g., alcohol and substance use; Andersen, 2003; Chambers, Taylor, & Potenza, 2003). Furthermore, it is during this developmental stage that age of onset of many psychiatric symptoms commonly occurs (e.g., schizophrenia, substance addiction, mood disorders; Chambers et al., 2003; Gogtay, Vyas, Wood, & Pantelis, 2011). This is important to remember when considering the sequelae of concussive injuries, especially in regards to symptomatic expression and neurocognitive disruption. Without baseline or longitudinal data causal links should not be made between sport-related concussion and post injury psychopathology.

Executive Function

Fields (2005) presents the process of myelination as a fundamental mechanism to activity-dependent plasticity through the regulation of the speed of conductivity, synaptic response, and potentiation. The development of these white matter fibre tracts has been associated with the development of motor skills, reading ability, and cognitive function as well as improved cognitive performance on tests of intelligence (IQ), learning, and memory (Schmithorst, Wilke, Dardzinski, & Holland, 2005; Yurgelun-Todd et al., 2002). These ‘high-level’ cognitive processes are often referred to as executive functions, which are necessary for all aspects of goal directed behaviour, attention, theory of mind, and other cognitive processes of the prefrontal cortex (Blakemore & Choudhury, 2006; Schmithorst et
al., 2005). Each of these executive functions has a role in cognitive control, for example developing and executing a plan, filtering out unimportant information, and inhibiting impulses. The ongoing myelination of axons in the prefrontal cortex and other association regions throughout childhood and adolescence suggests that the cognitive functions orchestrated in these region, such as attentional control, goal setting, and cognitive flexibility (i.e., working memory, problem solving, and strategic behaviour), are possibly still developing into young adulthood (Blakemore & Choudhury, 2006).

With ongoing maturation, children and adolescents are able to improve and develop their capacity for more efficient processing as the transmission of nerve impulses become more rapid with the increasing myelination of nerve tracts (i.e., axons; Anderson, Anderson, Northam, Jacobs, & Catroppa, 2001; Klingberg, Forssberg, & Westerberg, 2002). For example, Anderson and colleagues (2001) demonstrated a linear improvement of specific executive functions through their investigation of the cognitive performance of 11 to 17 year olds on a number of neurological tasks. Improvement during adolescence was observed on tasks of selective attention, working memory, and problem solving; whereas strategic behaviour seemed to have developed earlier in childhood. As these findings suggest, different aspects of executive function may have different developmental trajectories hence the functional and structural impact of developmental disturbance or brain trauma may be similarly varied.

Consequent of this ongoing development of the frontal region of the brain, adolescents have been found to be more vulnerable to the effects of concussion, and may experience ongoing and persistent disruptions to neuropsychological and executive functioning (Baillargeon, Lassdone, Leclerc, & Ellemberg, 2012; Howell et al., 2013; Iverson, Gaetz, Lovell, & Collins, 2004). In a retrospective study assessing sport-related concussion in children, adolescents, and adults, Baillargeon et al. (2012) found that
adolescents experienced persistent neurophysiological deficits up to 6 months following a concussive injury, and were also more sensitive to concussion-related cognitive disruption than adults. A head injury during this critical stage of development could result in deleterious effects on these cognitive components (Baillargeon et al., 2012; Iverson et al., 2004). Following the proliferation of cortical connections during the ‘sensitive period’ of puberty, the synaptic pruning that occurs is dependent on an individual’s interactions with their environment (i.e., cortical connections which are utilised frequently are maintained and strengthened, whilst connections which are not utilised are ‘pruned’). Therefore, disruptions in the development of executive function may have long-term implications for an individual’s cognitive and neuropsychological functioning, especially if injury goes unnoticed and proper recovery time is not employed (Iverson et al., 2004). As executive function is considered to encompass the highest levels of human functioning, and attention processes are considered fundamental to planned action, attention, and other prefrontal cognitive processes (Blakemore & Choudhury, 2006; Schmithorst et al., 2005), the monitoring of these cognitive elements in a population particularly vulnerable to the effects of sport-related concussion is essential.

Social Cognition

In addition to executive functions, the prefrontal cortex, specifically the medial prefrontal cortex, is also the brain region associated with the fundamental aspects of social cognition, such as theory of mind, self-referential processing (e.g., self-concept, self-reflection), and social appraisals (e.g., empathy, perspective taking; D'Argembeau et al., 2007; Sebastian, Burnett, & Blakemore, 2008). In addition to neural development, there are substantial changes in hormones throughout late childhood and adolescence as part of puberty. Although it is unfeasible to differentiate between the individual influences of each, together the significant neural and hormonal changes experienced during puberty stimulate changes in social cognition (Sebastian, Burnett, & Blakemore, 2008; Sebastian, Viding,
Williams, & Blakemore, 2010). During early adolescence, in place of parents, peers become more influential in shaping behaviour leading children to become more concerned with, and self-conscious of, other’s opinions (Sebastian, Burnett, & Blakemore, 2008; Sebastian, Viding, Williams, & Blakemore, 2010). The relatively stereotypical nature of these behavioural changes suggests a biologically determined remodelling of brain systems that motivate behaviour.

Although there are relatively few neuroimaging studies exploring the developmental shift in the neural processing of social cognition, results are consistent (see Sebastian et al., 2010 for review). The salient proposition from these studies is that the functional differences in social cognition throughout development are consequent of ongoing structural changes. Using functional magnetic resonance imaging (fMRI), Pfeifer, Lieberman, and Dapretto (2007) found that when processing self- and social knowledge the medial prefrontal cortex was activated in young adolescents, whereas the lateral temporal cortex was activated more in adults. As the lateral temporal cortex is associated with semantic memory retrieval, it can be suggested that adults have developed the ability to utilise stored self- and social memory while adolescents rely on prefrontal processing for self- and social processing (Pfeifer et al., 2007; Sebastian et al., 2010). Further, as myelination in the medial prefrontal cortex continues to develop throughout adolescence, the speed and efficiency of social appraisals and self-referential processing become more reflexive. This process of proliferation of prefrontal synapses and subsequent reorganisation and ‘pruning’ of unused synaptic connections throughout adolescence results in a net decrease in synaptic density in the frontal lobes (Blakemore & Choudhury, 2006; D’Argembeau et al., 2007).

**Risk Taking**

The protracted pruning of the pre-frontal cortex is indicative of growing frontal control over behaviour, the absence of which is associated with impulsivity and poor decision
Risk-taking behaviours appear to become more prevalent during adolescence, for example illicit drug use, excessive alcohol consumption, physical aggression, unprotected sex, and inadvertent injuries (e.g., car accidents). Spear (2007) and Casey, Jones, and Hare (2008) suggest that this increase in ‘risky’ behaviour may be due to the relatively early maturation of the frontostriatal dopamine reward circuits, which involve the nucleus accumbens, influencing adolescent’s motivation and reward seeking through increasingly novel activities. These activities often demonstrate the adolescent’s emerging independence away from the family (e.g., driving, sex; Romer, 2010; Spear, 2007). Spear (2007) identified this as a biological universal mammalian function to encourage the adolescent to venture away from the family to explore new territory and select mates. As is it a phenomenon observed in most mammals, Andersen (2003) proposed that the consistent preference for unfamiliar and novel environments and social interactions during adolescence is an inherent genetic drive (i.e., reduces chance of inbreeding).

During adolescence, ontogenic changes in dopamine levels and receptor density serve to facilitate and maximise learning about of new stimuli-action-outcome associations within the environment, however can also lead to obsessively focussed (and sometimes pathological) behaviours (Ernst, Romeo, & Andersen, 2009). Individual differences in sensation seeking and impulsivity have been associated with variation in the strength of this dopamine pathway (Chambers, Taylor, & Potenza, 2003). Further, Chambers and colleagues (2003) suggest that dopamine increases in the still-developing dorsal-striatal pathway (leading to the dorsolateral prefrontal cortex) during adolescence limits possible executive function and cognitive control over behaviour. Although increased dopamine activity within the prefrontal regions would suggest greater, and not lesser, modulation over behaviour, which is in contrast to the theoretical models of reduced cognitive regulatory control in adolescence (Yurgelun-Todd, 2007), it is the changes in dopamine receptor distribution that
influences changes in adolescent behaviour (Ernst, Romeo, Andersen, 2009). That is, adolescent behaviours are influenced more by dopaminergic striatal pathways than pathways in the amygdala (which regulated inhibition) and prefrontal cortex.

Recent developments in neuroimaging technology have allowed these developmental processes to be tracked and empirically studies in humans. For example, using fMRI, Galvan et al. (2006) found accumbens activity in adolescents was comparable to that of adults in both activity and dopamine reward sensitivity. Conversely, the frontal cortex activity in adolescents resembled that of children more than adults. These findings suggest that disproportionate activation and maturation of specific brain regions biases an adolescent’s behaviour towards immediate over long-term reward (Galvan et al., 2006). The hiatus between the development of these two pathways places adolescents at higher risk of impulsivity and mishap (Casey, Jones, & Hare, 2008; Chambers, Taylor, Potenza, 2003; Romer, 2010; Steinberg, 2007).

Although there is a marked increase in risk taking during adolescence, research suggests that individuals who are more likely to engage in impulsive and/or problematic behaviours exhibit these traits throughout childhood (Krueger et al., 2002; McGue & Iacono, 2005). Correlates of risky behaviour in adolescence are the relatively stable personality traits comprising the concept of ‘impulsivity’ (Romer et al., 2009; Whiteside & Lynam, 2001). Indeed, the spectrum of risk taking and problem behaviours appear to be related to a core set of impulsive traits that are evident in early development (McGue & Iacono, 2005). There have been numerous attempts to clarify the construct of impulsivity within personality theories (see Whiteside & Lynam, 2001 for review). Despite attempts to conceptualise impulsivity within personality theory, none of the frameworks presented by theorists have been unequivocal. Romer (2010) and Romer and colleagues (2011) presented impulsivity as a multidimensional trait comprised of three potentially independent forms; ‘impatience’,
'acting without thinking', and 'sensation seeking'. Impatience (i.e., selection of a smaller immediate reward over a larger delayed reward; also known as delay discounting), acting without thinking (i.e., uninhibited and hyperactive temperament with limited attention to the environment), and sensation seeking (i.e., experimentation with exciting and novel activities despite the associated risks) are each associated with weaknesses in executive function. For example, a consistent negative interaction between impatience and working memory as well as intelligence has been found (Shamosh et al., 2008). In addition, assessments of impatience, or delay discounting, have been found to be reliable and stable over time (Ohmura, Takahashi, Kitamura, & Wehr, 2006). Indeed, impulsive traits observed in children as young as 3 years old can predict later problems in behaviour (Caspi, Henry, McGee, Moffitt, & Silva, 1995; Tarter et al., 2003). Furthermore, when assessed in a community sample of 387 preadolescents, aged 10 to 12 years, acting without thinking and sensation seeking were found to correlate significantly with risk taking behaviour later in life (Romer et al., 2009). These studies highlight how impulsivity, when assessed as a multidimensional trait, can be used to identify early manifestations of risk taking behaviour. Further, early identification of the trajectory of risk taking behaviour in childhood can be predictive of problem behaviour later in adolescence.

While risk taking can be seen as a developmentally ‘normal’ product of biological changes during adolescence, Greene and colleagues (2000) proposed risk taking as a negative by-product of cognitive development, specifically egocentrism. Egocentrism is generally regarded as an overall focus on self which reduces differentiation of subject-object interaction inducing a sense on invulnerability (Greene et al., 2000; Piaget, 1958). This perspective emphasises judgement errors resulting from perceived ‘uniqueness’ which stems from an under-differentiation of object of thought (i.e., ‘imaginary audience’, that is, everybody is focussed on the same thoughts as oneself; Elkind, 1967), in accordance with an over-
differentiation of self from others (also known as ‘personal fable’ which is negatively associated with perceived susceptibility; Elkind, 1967). Thus, from this perspective, risk taking behaviour in adolescence may not be an error in judgement, rather a failure to recognise that a judgement is necessary due to confounded feelings of uniqueness and invulnerability.

When applied in a sport setting, attitudes towards risk taking have important implications for an athlete’s perceived susceptibility to injury as well as return to play attitudes. Specifically, the sense of invulnerability and specialty associated with risk-taking in adolescents (Elkind, 1967) may impede young athletes’ ability to appraise risk as severe injury is something that happens to ‘other people’. Subsequently, this perceived sense of uniqueness may decrease both reporting behaviours and recovery compliance, especially when removal from participation may be seen as a form of punishment or exclusion. Although egocentrism and risk taking behaviours typically decline as individuals progress through adolescence (Elkind, 1967), the implications of these behaviours in the sport setting are important to consider.
Chapter Three – Rugby Union and the Biopsychosocial Benefits of Team Sport Participation

In Australia, 63% of children aged 5 to 14 years of age participate in some form of organised sport (Australian Bureau of Statistics [ABS], 2012). Furthermore, approximately 3.8 million (22%) Australians aged 15 years and older actively participate in organised sport, (ABS, 2012). As more than just an enjoyable activity, team sports offer a range of valuable benefits to players; providing the chance for at least four fundamental aspects of development for children and adolescents, including acquisition of motor skills, improved physical fitness, opportunities to learn life skills (e.g., discipline, leadership, and self-control), and psychosocial development (e.g., peer interaction, co-operation, mateship; Fraser-Thomas & Côté, 2006). The skills taught and practiced during team sport participation facilitate and encourage the development and refinement of children’s gross and fine motor skills as well as awareness of their physical abilities.

The Rugby Rundown

Rugby Union (rugby) is a game that is played in over 120 countries throughout the world with particular popularity in Australia, Britain, New Zealand, South Africa, and France. In 2011, approximately 261,473 Australians were playing rugby (over a 25% increase since 2006), 77% of whom were made up of primary and high school aged children (Australian Rugby Union [ARU], 2012). Since its development in 1823, rugby has been seen as a team sport in which leadership, discipline, mateship, sportsmanship, and community pride are taught and facilitated through the rules of gameplay. The object of this ‘end zone invasion’ game is to score as many points as possible, by carrying, passing, kicking, and grounding the ball with the team scoring the greater number of points being the winner of the match. Rugby is a game of continuous flow with typically 15 players in each team consisting of ‘forwards’ (jersey numbers 1 to 8) and ‘backs’ (jersey numbers 9 to 15). The ‘forwards’,
who are often physically bigger players, are the athletes who form the ‘scrum’ while the ‘backs’ are used to run the ball. When a player is running with the ball they may be brought to the ground and held (i.e., tackled) to contest possession of the ball. During play the ball is transferred between teammates by backwards passes, if the ball is dropped forward (knock-on) or passed forwards gameplay is stopped. To restart play a ‘scrum’, made up of eight forwards from each team, is formed by interlocking shoulders and leaning forward against the opposing team (see Figure 1). The ball is rolled into the tunnel between the opposing teams and hooked back by the players until possession of the ball is gained. Rugby is a sport which exposes players to frequent high impact collision.

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1. Loose head Prop
2. Hooker
3. Tight head Prop
4. Lock
5. Lock
6. Blind side Flanker
7. Open side Flanker
8. Number 8
9. Scrum half
10. Fly half
11. Left Wing
12. Inside Centre
13. Outside Centre
14. Right Wing
15. Full Back

Figure 1. Typical scrum formation in rugby union.

While ‘dangerous’ foul play behaviour is not tolerated at any level of competition, the nature of the game is considerably physical, thus traumatic injury can occur to the body, neck, and head. The rules of play are formulated and reviewed every four years by the International Rugby Board (IRB) and include special considerations for athletes under 19-, 12-, and 8- years old. Designed to minimise sport-related injury risk, the adaptations for junior rugby take differences in maturation and ability into consideration. For example, rule
modifications in junior rugby include changes to the size of the field, the duration of the
game, team numbers, and scrum and lineout engagement (World Rugby [IRB], 2014). From
under 15s and over, full contact game rules typically apply (e.g., lifting at lineouts, as well as
contested scrums, rucks, and mauls; IRB, 2014).

Benefits of Team Sport Participation

Government and health authorities, both in Australia and globally, continue to
highlight the concerning increase in childhood obesity, inactivity, and subsequent long-term
health implications such as diabetes, chronic heart disease, and some cancers (Australian
Department of Health and Aging, 2012; Dobbins, DeCorby, Robeson, Husson, & Tirilis,
2009). The World Health Organisation (WHO) estimated that 1.9 million deaths throughout
the world can be attributed to physical inactivity (2004). In addition to developing healthy,
and often lifelong, physical activity habits, participation in physical team sport facilitates
cardiovascular fitness, weight control, muscular strength and endurance, flexibility, and
healthy bone structure (Dobbins et al., 2009; WHO, 2004).

Social identity. The unique learning environment offered through team sport
participation facilitates the formation of identity and a range of cultural knowledge and social
skills not present in any other context. Humans, as typically social beings, have an inherent
need to identify and associate with others (Wann, 2006). According to social identity theory,
an individual’s self-concept encompasses both a personal identity (e.g., skills, beliefs) and a
social identity (i.e., shared group classification). Social identification facilitates an
individual’s means of organising their social environment and locating their place within it.
By identifying with a group, people perceive themselves as psychologically intertwined,
enabling them to internalise the status and successes of the group which has been shown to
lead to enhanced self-esteem (Mael & Ashforth, 2001; Wann, 2006). Through identification
with a social identity or group, the psychological support gained by individuals through this
social networking can lead to lower rates of depression, anxiety, and loneliness (Boone & Leadbeater, 2006; Compton, 2005; Wann, 2006). In adolescents, the psychosocial benefits of team sport participation also include improved social adjustment (McHale et al., 2005); development of teamwork, leadership skills, cooperation, and task commitment (i.e., increased effort; Dyson, Griffin, & Hastie, 2004); resistance against drug and alcohol addiction, and more favourable self-image (Kirkcaldy, Shephard, & Siefen, 2002).

During the transition into adolescence, children are at heightened risk for both academic and social difficulties such as self-esteem, academic attainment, increased drug and alcohol problems, and involvement in delinquency and other negative peer pressures (Eddy, Reid, Stoolmiller, & Fetrow, 2003; McHale et al., 2005). In their study examining the patterns of adjustment amongst urban middle-school aged children (12 to 13 years of age), McHale and colleagues (2005) questioned 423 students (216 males and 207 females) on their sporting involvement, self-esteem, delinquent activity, and drug use in the year preceding the study. The students’ physical education teachers were also asked to rate each participant’s social competence, shyness, and aggression (McHale et al., 2005). The significant findings of this study indicated that youth who were involved in sport had normal levels of aggression, were less likely to experiment with illicit drugs, reported higher self-esteem, and were rated as more socially competent than non-involved children. Although the absence of a repeated measure design in this study prevents a causal relationship from being inferred, studies such as Bruner, Eys, Wilson, and Côté (2014) and Kirkcaldy et al. (2002) have found that it is the social adhesive properties of participation in a team sport that have a more pertinent contribution to psychological well-being than participation in physical activity alone. Kirkcaldy et al. (2002) in finding that regular physical activity improved self-image and drug/alcohol resistance, posited that it may be the social aspects of physical activity among adolescents which are the determinants of psychological wellbeing.
In review Compton (2005) noted that psychological well-being, general happiness, and life satisfaction were all predicted by positive social relationships. This interaction has been extended into investigations of the relationship between mental health and group-based sporting activities (Compton, 2005; McHale et al., 2005). Compared to individuals with low social identification, individuals who reported having a strong psychological connection with their sporting group or team (i.e., have high social identification to the group) have expressed higher levels of social and personal self-esteem; social well-being; openness, conscientiousness, and extroversion; and more frequent positive emotions (Wann, 2006; Wann & Pierce, 2005). Furthermore, people with high social identification have also been found to experience lower levels of loneliness, depression, fatigue, and experiences of negative emotion (Wann, 2006; Wann & Pierce, 2005).

Cognitive development. Participation in physical activity has also been shown to have a positive effect on cognition and concentration throughout development through both physiological and psychological mechanisms (Etnier, Nowell, Landers, & Sibley, 2006; Taras & Potts-Datema, 2005). This neurological benefits of regular physical exercise on the developing brain has been illustrated in early animal studies, such as those conducted by Black and colleagues (1987; 1990). In these studies it was consistently found that when raised in complex environments (i.e., when provided with toys, exploration, and play), rats developed a greater density of synapses (greater learning retention) and higher capillary volumes (increased cognitive stamina) these studies were unable to separate whether physiological benefit was consequent of learning opportunities or due to physical exercise. Extensive human research has also found aerobic fitness, in both children and adults, to be associated with selective improvements in neurocognitive functions, such as executive functioning, which refers to a subset of goal directed functions encompassing cognitive flexibility, coordination, concentration, inhibition, and working memory (Colcombe et al.,
2003; Etnier et al., 2003; Hillman et al., 2009). In a study by Hillman and colleagues (2009) the effect of aerobic fitness on the cognitive development was assessed in 38 children (19 scored as having high fitness, 19 scored as having low fitness), ranging from 8 to 11 years of age. In addition to exhibiting greater response accuracy and response time in cognitive assessment tasks such as the Eriksen’s flanker task, neuroelectric data collected using an EEG also supported fitness-related differences in task performance. These findings suggest that aerobic fitness has the potential to increase the development and improvement general cognitive function in preadolescent children (Hillman et al., 2009).

The benefits of sport participation on physical, cognitive, and psychosocial health and development have been widely demonstrated throughout research. The additional developmental and health benefits associated with team sport participation highlights the need for these activities to be encouraged, especially in adolescent populations. As with any physical activity, there is a notable increase in the risk of sustaining an injury. While this also presents many legitimate concerns, sport-related injury should be considered relative to the substantial advantages to health and development that are presented in the unique contexts of team sport.
Chapter Four – The Relative Incidence of Concussion

Risk in Sport

Concussion is probably the hottest topic in sports injury currently (McCrory et al., 2013) with voracious media coverage and exploding research interest (Caine, Purcell, & Maffulli, 2014). However, the recent focus on concussion in sport is often dominated by individual and societal perception rather than actual level of risk. Despite discrepancies in injury definitions, reporting methods, reporting accuracy, and confounding demographics; cycling, motor sports, skiing/snow sports, and equestrian were consistently presented as some of the most common causes for sport-related concussion in Australia (Helps, Henley, & Harrison, 2008). Additionally, team sports such as Australian football (AFL), rugby union, rugby league, and soccer are also noted as activities with a high rate of concussion and head injury (Helps, Henley, & Harrison, 2008). Sport-related concussion is a multi-faceted issue; thus objective assessment is needed to ensure balanced prevention and management of sport-related concussion, without losing sight of the many benefits of sport involvement.

Understanding Risk

Everyday life is characterised by a certain level of uncertainty, a condition that brings the unforeseen consequences, both positive and negative, that are a fundamental aspect of social life. Unfortunately stringent governance of rulings and procedures often fail to completely ameliorate the likelihood of accidents occurring, as they are just that – accidents. The concept of the ‘risk of injury’ for any activity refers to the severity of possible consequences and the probability that these adverse events might occur (Fuller, 2008). While ranking risk does provide an effective way of assessing an activity’s acceptable cost-versus-benefit, it is recognised that considering an activity’s single risk value can be misleading as it often overlooks the inherent differences in the different types of activities that can be
The classification of what is deemed an ‘acceptable level of risk’ cannot be calculated, as acceptance is subjective to people’s individual perceptions of risk-benefits and the current norms within society. Media attention and ‘prevention’ funding is often placed on ‘high profile’ hazards, which raises important questions about how people perceive relative risk. For example, Brander et al. (2013) highlighted that, in Australia, rip currents are responsible for more human deaths than bushfires, floods, cyclones, and sharks combined. However, consequent of catastrophic natural disasters and terrifying shark attacks attracting more media and social attention, Australians are more likely to associate these events with high risk of danger while ‘low intensity-high frequency’ hazards, such as rips, are more often overlooked (Brander et al., 2013). Similarly, while young people are more likely to experience a concussion and head injury from an accidental fall (e.g., tripping over a chair, falling off a trampoline), however consequent of recent media attention and social awareness of sport-related concussion – especially in contact sports such as football – the perception of injury risk in these activities is perceived as higher, compared to more pedestrian activities.

**Individual perceptions of injury risk.** As children gain more control over their physical bodies (e.g., learning to walk, ride bicycles etc.) and independence in their environments (i.e., participating in activities away from their parents such as school and sport), naturally their exposure to risk increases. The Australian Institute of Health and Welfare (AIHW; 2008) reported 954 deaths of young Australians due to injury in 2005, which is a rate of 26 deaths per 100,000 young people. Of these deaths, ~4% were adolescents aged 12 to 14 years old, ~17% were aged 15 to 17 years old, and ~80% were aged 18 to 24 years old (AIHW, 2008). The independence and increased responsibility young people begin to explore, particularly those aged 15 to 17 years, occurs simultaneously with
exposure to alcohol and other drugs, and the development of new skills (e.g., operating a motor vehicle), at a time when peer acceptance and social desirability are perceived as imperative.

Despite the well documented increase in risk taking behaviour during adolescence, research suggests that individuals who are more likely to engage in impulsive and/or problematic behaviours exhibit these traits throughout childhood (Krueger et al., 2002; McGue & Iacono, 2005; Vassallo et al., 2007). From this it can be suggested that individuals who are likely to experience injuries due to low self-calculated risk estimations are likely to be ‘accident prone’ both throughout their lives and across different environments. Risk perception is often a precursor to actual behaviour, with research indicating that perception of risk negatively related to overall risk behaviour (Greene et al., 2000). Although risk taking can be seen as a developmentally ‘normal’ product of biological changes during adolescence (e.g., transitions in dependent to self-directed social roles, physical and hormonal changes) it is also associated with egocentric behaviours which reduces differentiation of subject-object interaction inducing a sense of invincibility. From this perspective, risk taking behaviour in adolescence may not be an error in judgement, rather a failure to recognise that a judgement is necessary due to confounded feelings of uniqueness and invulnerability (Greene et al., 2000).

The lack of identification of the specific characteristics which may place an individual more at risk of sustaining a sport-related injury presents a notable gap in current research (Clacy, Sharman, & Lovell, 2013a). Human factors, such as personality, have been found to contribute to an individual’s risk of injury (Machin & Sankey, 2008; Morrongiello & Sedore, 2005; Zuckerman, 2006). Personality factors such as sensation seeking, aggression, and egocentrism are expressed in risky behaviours in many domains such as extreme/high risk sports, vocation choice, substance use/abuse, sex practices, and crime (Zuckerman, 2006).
For example, sensation seeking (which is considered a stable personality trait) is associated with daring, thrill-seeking behaviours, and the need for novelty and risk exposure, and has been found to be both a direct predictor of risk perception through behaviour as well as an indirect predictor through its negative influence on aversion to risk taking (Machin & Sankey, 2008; Zuckerman, 2006). Consistent with research on adolescents and adults, Morrongiello and Sedore (2005) found that children (mean age 9.4 years) who exhibited sensation seeking personality traits were more likely to engage in risk taking behaviours and experience more excitement than fear in high-risk situations.

Compared to adults, adolescents are liable to minimise their perception of risk when involved in experimental and health-threatening activities (Boyer, 2006). Adolescents have been found to be significantly less optimistic about their ability to avoid injury, suggesting an external locus of control (Millstein & Halpern-Felsher, 2002). In a study of 90 children it was found that individuals who exhibited more risk-taking behaviours were found to attribute injury more to ‘bad luck’ than to their own actions (Morrongiello & Sedore, 2005). Additionally children with more risk taking behaviours also believed themselves to be less likely to be injured than their peers (Morrongiello & Sedore, 2005). These findings indicated that despite previous or frequent injury, some children may maintain high or inflated estimations of their abilities and low estimates of injury risk. Conversely, Kontos (2004) found that low perceived risk and low estimation of ability are significant risk factors for injury in 11 to 14 year olds. It is suggested that this may be due to the climate wherein difficult and risky behaviours are attempted without a concomitant belief in a successful outcome (Kontos, 2004). Although research regarding the influence of ability (perceived or actual) and risk of injury are inconclusive, adolescents’ low estimations of risk of injury are consistently found increase the likelihood of participation in risk taking behaviours and subsequent injury (Boyer, 2006). Risk taking behaviour can be seen to play a significant role
in determining the likelihood of injury among children and adolescents who play contact
sport, especially in sports such as rugby in which activities such as tackling and scrumming
for possession are readily executed despite the physical risk involved.

**Australian Injury Statistics**

In Australia the risk of hospitalisation due to concussion as the primary diagnosis is
highest from 15 to 25 years old, with an incidence rate of 240 per 100,000 persons (Helps,
Henley, & Harrison, 2008). Based on a national report of hospitalisations due to mTBI (see
Table 2), some of the main causes of concussion from 2004 to 2005 in Australia were
accidental trips/falls (~42.2%), transport related injuries (~29.4%), participation in sporting
and other recreational activities (~15.6%; 32.4% of which were identified as being a football-
related injury), and physical assault (~14.5%). In almost all categories and age groups males
were consistently at greater risk of head injury compared to females (Helps, Henley, &
Harrison, 2008).

While there have been some comparative reviews of the incidence of sport-related
concussion in different sports in the past decade (e.g., Finch, Clapperton, McCrory, 2013;
King et al., 2014), calculating the incidence of sport-related concussion is complicated due to
several issues, such as methodological discrepancies and underreporting. Variations in the
classification of concussion, as well as within- and between- sport inconsistencies in
incidence recording (e.g., incidence as a percentage vs. per 1000 hours), has led to confusing
and often incomparable statistics. Furthermore, existing research has often focused on
professional and hospitalised samples, often overlooking regional and remote areas, which
record higher injury incidence rates compared to major cities (Kreisfeld, Harrison, & Pointer,
2014).
Research into concussion and mTBI has demonstrated that irrespective of the legislation and stringent governance of activities such as driving a car or riding a bicycle, head injuries in children and adolescents still occur frequently (e.g., Finch, Clapperton, 7 McCrory, 2013; Harris et al., 2012). Despite this, when the costs-versus-benefits and the social norms and expectations regarding adolescents getting their driving licence and children learning to ride a bicycle, the relative risk of injury is typically deemed as ‘acceptable’. This classification of an ‘acceptable risk’ is developed by the acceptance that these activities are governed (i.e., there are rules and procedures that are strictly enforced, such as abiding by a speed limit or wearing a helmet) and that there are obvious benefits associated with these

| Table 2. Main causes of mTBI as principal diagnosis for hospitalisations in Australia, 2004-05* |
|-----------------------------------------------|-----------------|-----------------|-----------------|
|                                               | Total           | Females         | Males           |
| Accidental trips/falls                        | 42.2            | 53.2            | 37.1            |
| Transport related injuries (total)            | 29.4            | 29.0            | 29.6            |
| - as driver/operator.**                       | 63.0            | 57.6            | 66.1            |
| - as passenger                                | 27.5            | 34.0            | 23.9            |
| Sport/recreational activities (total)         | 15.6            | 10.2            | 18.0            |
| - Football (all codes)                        | 32.4            | 9.9             | 38.2            |
| - Cycling                                     | 11.3            | 9.5             | 11.8            |
| - Motorcycling                                | 9.2             | 3.1             | 10.9            |
| Physical assault                              | 14.5            | 7.5             | 17.6            |


Cost-Benefit versus Social Expectation

...
activities (e.g., physical activity, independence). The socially supported acceptance of these ‘high risk’ activities impedes the thorough assessment of the more subtle similarities, such as individual characteristics (e.g., age, gender, sensation seeking), that may impact the incidence and outcome of concussive injury sustained while participating in activities such as learning to ride a bicycle or drive a car.

**Limitations and Inconsistencies in Previous Research**

Sport-related concussion and the possible cumulative and enduring impact of mTBI on long-term brain function is a complex issue that has been inconsistently researched. While there have been some comparative reviews of the incidence of sport-related concussion in different sports in the past decade (see Table 3) calculating the incidence of sport-related concussion is complicated due to methodological discrepancies. Table 3 summarizes some of the published, peer reviewed journal articles exploring sport-related concussion incidence. These were located using Google Scholar and ProQuest. The search was limited to; (a) concussive/head injuries sustained while participating in sport, and (b) reviews published post 2000, to ensure statistics were reflective of current participation. Focus on a child/adolescent participant sample was originally considered, however mean participant age was [strangely] not a consistently reported variable.
<table>
<thead>
<tr>
<th>Authors</th>
<th>Time Period</th>
<th>Location</th>
<th>Sample</th>
<th>Incidence rate/s by sport</th>
<th>Statistics reported</th>
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<tr>
<td>R. Kreisfeld, J. E. Harrison, &amp; S. Pointer</td>
<td>2011-2012</td>
<td>Hospital separations due to head injury, AUS.</td>
<td>n=36, 237 (77% male); 65% of sample were &lt;35y/o.</td>
<td>AFL 735 (36% ICI)</td>
<td>Number of reported head injuries; percentage of the reported head injuries that were intracranial (ICI).</td>
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<td>C. F. Finch, A. J. Clapperton, &amp; P. McCrory</td>
<td>2002-2011</td>
<td>Public and private hospital admissions due to head injury in Victoria, AUS.</td>
<td>n= 28,718 (4745 sport-related) (16.5%); ≥ 15y/o.</td>
<td>Motor cycling/scooter/ATV 181.8 (n=674; 14%)</td>
<td>Mean rate per 100,000 participants; number of reported concussions (n); percent of sport-related head injuries.</td>
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<td>D. King, C. Gissane, M. Brughelli, P. A. Hume, &amp; J. Harawira</td>
<td>2001-2011</td>
<td>Sport-related concussion Accident Compensation Corporation (ACC) claims, NZ.</td>
<td>n = 1330 (84% male); participant ages ranged from 10 to 39 years (mean data not available).</td>
<td>Rugby Union: 38.4 (n = 802)</td>
<td>Rate per 1000 minor and moderate-to-serious claims recorded by the ACC; number of reported concussions (n).</td>
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<td>Rugby League: 8.6 (179)</td>
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<td>Netball: 3.5 (74)</td>
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<td>Accident Compensation Claim Corporation</td>
<td>2009-2013</td>
<td>Sport-related concussion Accident Compensation Corporation Claim Corporation (ACCC), NZ.</td>
<td>n = 25,445 new ACCC claims for minor and moderate-to-serious concussive injury claims.</td>
<td>Rugby Union: n = 7926 (31%)</td>
<td>Number of reported concussions (n); percent of new ACCC injury claims over 4 years.</td>
</tr>
<tr>
<td></td>
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<td></td>
<td>Soccer: 1706 (7%)</td>
<td></td>
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<td></td>
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<td></td>
<td></td>
<td>Rugby League: 1625 (6%)</td>
<td></td>
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<td></td>
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<td></td>
<td></td>
<td>Netball: 528 (2%)</td>
<td></td>
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<td></td>
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<td></td>
<td></td>
<td>Cycling: 1640 (6%)</td>
<td></td>
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<td></td>
<td>Horse Riding: 1434 (6%)</td>
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<td></td>
<td></td>
<td></td>
<td>Trail Biking/MotorX: 505 (2%)</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Skiing/Snowboarding: 2528 (10%)</td>
<td></td>
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</tbody>
</table>
Table 3. Comparative incidence of sport-related concussion statistics cont.

<table>
<thead>
<tr>
<th>Authors</th>
<th>Time Period</th>
<th>Location</th>
<th>Sample</th>
<th>Incidence rate/s by sport</th>
<th>Statistics reported</th>
<th>Authors</th>
</tr>
</thead>
<tbody>
<tr>
<td>W. Harris, C. A.</td>
<td>1997-2008</td>
<td>Emergency department</td>
<td>n=4887; 0-35y/o</td>
<td>Hockey</td>
<td>19.3 (n=1013; 20.7%)</td>
<td>Rate of SR head injuries per 100,000 population treated in emergency departments; n of reported concussions; percent of total n.</td>
</tr>
<tr>
<td>Jones, B. H.</td>
<td></td>
<td></td>
<td></td>
<td>Cycling/BMX</td>
<td>11.0 (581; 11.9%)</td>
<td></td>
</tr>
<tr>
<td>Rowe, D. C.</td>
<td></td>
<td></td>
<td></td>
<td>Skiing/Snowboarding</td>
<td>10.0 (524; 10.7%)</td>
<td></td>
</tr>
<tr>
<td>Voaklander</td>
<td></td>
<td></td>
<td></td>
<td>Soccer</td>
<td>8.2 (433; 8.7%)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>American football</td>
<td>6.0 (313; 6.4%)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Skating/Skateboarding</td>
<td>4.7 (246; 5%)</td>
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<tr>
<td></td>
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<td></td>
<td></td>
<td>Playground equipment</td>
<td>4.7 (246; 5%)</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>Rugby (both codes)</td>
<td>3.4 (179; 3.7%)</td>
<td></td>
</tr>
<tr>
<td>J. Gilchrist, K.</td>
<td>2001-2009</td>
<td>Nonfatal hospital</td>
<td>n=173, 285; ≤19</td>
<td>Cycling</td>
<td>n=26,212 (15.1%)</td>
<td>Number of reported concussions in the study (n); percent of total n.</td>
</tr>
<tr>
<td>E. Thomas, L.</td>
<td></td>
<td></td>
<td></td>
<td>Football (unspecified)</td>
<td>25,376 (14.6%)</td>
<td></td>
</tr>
<tr>
<td>Xu, L.</td>
<td></td>
<td></td>
<td></td>
<td>Soccer</td>
<td>10,436 (6%)</td>
<td></td>
</tr>
<tr>
<td>McGuire, &amp; V.</td>
<td></td>
<td></td>
<td></td>
<td>Motor sports</td>
<td>9707 (5.6%)</td>
<td></td>
</tr>
<tr>
<td>Coronado</td>
<td></td>
<td></td>
<td></td>
<td>Equestrian</td>
<td>3638 (2.1%)</td>
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</tr>
</tbody>
</table>
Table 3. Comparative incidence of sport-related concussion statistics cont.

<table>
<thead>
<tr>
<th>Authors</th>
<th>Time Period</th>
<th>Location</th>
<th>Sample</th>
<th>Incidence rate/s by sport</th>
<th>Statistics reported</th>
</tr>
</thead>
<tbody>
<tr>
<td>Y. Helps, G. Henley, &amp; J. E. Harrison</td>
<td>2004-2005</td>
<td>National hospitalisation statistics, AUS.</td>
<td>Principal diagnosis (specified activity)</td>
<td>Football (all codes)</td>
<td>n=715 (52.4%) Number of reported concussions in the study</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Cycling</td>
<td>250 (18.3%) (n); percent of total n.</td>
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<td></td>
<td>Motor sports</td>
<td>205 (15.1%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Equestrian</td>
<td>144 (10.5%)</td>
</tr>
<tr>
<td>S. J. Hollis et al.</td>
<td>2005-2007</td>
<td>Regional Sydney rugby union clubs, AUS.</td>
<td>n=3207; males only; 15-49 y/o</td>
<td>Rugby Union (non-professional)</td>
<td>7.97 (314; 9.8%) Rate per 1000 game hours; n of reported concussions; percent of total n.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(m=22.7y/o, SD=5.5).</td>
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</tbody>
</table>
Variations in the classification of concussion as well as within- and between-sport inconsistencies in incidence recording (e.g., incidence as a percentage vs. per 1000 playing hours) has led to confusing and often incomparable statistics. For example in two different Australian meta-analyses of concussion rugby players’ incidence differed from ‘0.6 to 5.0 per 1000 player game hours’ (Koh, Cassidy, & Watkinson, 2003) to ‘7% of all rugby-related injuries’ (McIntosh, Best, Orchard, & Savage, 2004). In many national sport-related injury reports rates of injury are calculated using two different denominators; national population data and participation-based population data (as reported in the annual participation in sport and physical recreation survey conducted by the ABS) to arrive at a rate per 100,000 people (e.g., Finch, Clapperton, & McCrory, 2013; Harris, Jones, Rowe, & Voaklander, 2012; Helps, Henley, & Harrison, 2008; Kreisfeld, Harrison, & Pointer, 2014). These data however, are frequently based on hospitalised injuries. Although injuries are coded using standardised clinical coding and classifications (i.e., ICD-10-AM), activity codes are often not assigned to injuries, meaning that the reported statistics are non-specific and likely to be an underestimate of the true extent of hospitalised sport injury (Finch & Boufous, 2008; Kreisfeld, Harrison, & Pointer, 2014; McKenzie et al., 2009). Furthermore, existing research has often focused on professional and hospitalised samples, often overlooking regional and remote areas, which record higher injury incidence rates compared to major cities (Kreisfeld, Harrison, & Pointer, 2014). Despite these discrepancies, cycling, motor sports, skiing/snow sports, and equestrian are consistently presented as some of the most common causes for sport-related head injury, in addition to team sports such as Australian football (AFL), rugby union, rugby league, and soccer (see Table 3).

Underreporting and the often limited medical support on the sidelines available to correctly identify and diagnose a concussion further impede the calculation of mTBI incidence in sport (Hollis et al., 2012; McCrea et al., 2004). This is particularly an issue in
adolescent sport where concussive injuries are often go unreported consequent of injuries being downplayed and athletes not wanting to be withdrawn from participation (Chrisman, Quitquit, & Rivara, 2013; McCrea et al., 2004). It is important to note that most high school football players are often able to identify the symptoms of concussion, despite this many athletes admit they would continue to play (Chrisman, Quitquit, & Rivara, 2013; Hollis et al., 2012). In a qualitative study on high school varsity football and soccer players, the lack of specificity regarding concussion symptoms was often found to be a barrier to reporting injury as athletes are unable to determine if they were serious enough to report; especially as concussion may not cause any significant pain or impair play (Chrisman, Quitquit, & Rivara, 2013). This lack of specificity stems from the paucity in the definition presented by the consensus statement on concussion in sport (McCrory et al., 2013) as it fails to note the overlap between the symptoms of concussion and other common injuries and disorders (Craton & Leslie, 2014). Chrisman, Quitquit, and Rivara (2013) found that in test scenarios athletes had difficulty identifying concussion, as the presenting symptoms were nonspecific and could have been due to another aetiology, such as dehydration (a ubiquitous concern when running around on a hot football field).

**The Bigger Picture**

Government and health authorities, both in Australia and globally, continue to highlight the concerning increase in childhood obesity, inactivity, and subsequent long-term health implications such as diabetes, chronic heart disease, and some cancers (Australian Department of Health and Aging, 2012). It is estimated that physical inactivity contributes to 13,500 deaths each year in Australia and accounts for around 7% of the total burden of disease and injury (Kreisfeld, Harrison, & Pointer, 2014). Participation in physical team sport addresses this major health issue through the facilitation of cardiovascular fitness, weight control, muscular strength and endurance, in addition to offering a plethora of other
benefits to children and adolescents including improved social adjustment, development of teamwork, leadership skills, cooperation, and task commitment (McHale et al., 2005); resistance against drug and alcohol addiction, and more favourable self-image (Kirkcaldy, Shephard, & Siefen, 2002). Furthermore, studies have found that it is the social adhesive properties of participation in a team sport that have a more pertinent contribution to psychological well-being than participation in physical activity alone (e.g., Kirkcaldy et al., 2002; McHale et al., 2005). In comparison to people with lower social identification, individuals who report having a strong connection with their sporting team express higher levels of social self-esteem and social well-being, as well as lower levels of depression, anxiety, anger, and loneliness (Wann, 2006). While concussion is a genuine concern in contact sport, the relative risk must be assessed by looking at the overall cost-versus-benefit of the activity. The undertow of media and emotive parental responses propelling the ‘demonization’ of specific activities and sports deemed as ‘too dangerous’ consistently overlooks the real crux of the problem.

Statistically speaking, young people are more likely to be hospitalised for a concussion from tripping over a chair or being in a car accident than they are from playing sport, let alone specifically playing rugby (Helps, Henley, & Harrison, 2008). What the majority of head injury and risk research findings have in common is a specific ‘type’ of person who is likely to engage in higher risk activities, exhibit more risk taking behaviour, and subsequently sustain a concussive injury. Despite growing public awareness of the severity of sport-related concussion and the increased volume of research and awareness in professional sports, such as rugby, there is still a considerable lack of evidence regarding not only the symptomology and definition of concussion (Craton & Leslie, 2014; Patricios & Makdissi, 2014), but also what factors may place an individual athlete at higher risk of becoming concussed and the subsequent prolonged effect of cognitive disruption (if any)
following concussion (Clacy, Sharman, & Lovell, 2013b). There is no question that sport-related concussion in children and adolescents needs to be understood more comprehensively. Discordant injury reporting methods and biased assessment of risk are just the beginning of some of the issues that need to be globally reconsidered in the sporting community. Sport-related concussion is a multi-faceted issue, and while some of these facets have been scrutinised in research, it is often out of context of the other significant aspects of concussive injury. Before sports such as rugby are red carded forever, sport-related concussion risk needs to be assessed with consideration for the ‘bigger picture’, ensuring balanced prevention and concussion management strategies without losing sight of the many benefits of sport involvement.
Chapter Five – Sport-Related Concussion Incidence in Junior Rugby Union

Sport-related concussion is a multi-faceted issue which needs to be understood in context, with consideration for the biological, psychological, and psychosocial factors which influence the incidence of injury in contact sport. The identification of risk factors which predispose an athlete to concussion may further our understanding of the underlying mechanisms of concussion and aid in the improvement of prevention and management strategies. Thus the application of the Biopsychosocial Model (Engel 1977, 1980) is a useful framework to apply as it prescribes a fundamentally different path from the traditional cause-and-outcome method of understanding. Using this model it is proposed that to better understand the risk factors to sport-related concussion, intrinsic and extrinsic variables within the biological (physical), psychological, and social domains should all be considered. Using the Biopsychosocial Model, both immediate (e.g., use of protective gear, age, BMI) and peripheral (e.g., cognitive functioning, social factors) factors will be considered. This addresses many limitations in existing literature as it intentionally considers factors which are often omitted from studies. This has previously been the case in many studies where children with premorbid learning or behaviour problems are excluded from studies, despite the possibility that these conditions may increase their risk of sustaining a concussion (Yeates, 2010). It also encourages the individual consideration of factors that may not be generically applicable to athletes of all ages, such as identity and social cohesion (Brewer et al., 1998).

Intrinsic and Extrinsic Risk

Factors associated with sport-related injury incidence, causality, and aetiology include the interaction of intrinsic biological and psychological characteristics and actions of the athlete with the extrinsic physical and social characteristics and events of the sport environments (see Figure 2; Wiese-Bjornstal, 2010). Intrinsic characteristics include the individual biological and psychological variables which predispose an athlete to injury, such
as body composition and risk taking behaviours (Wiese-Bjornstal, 2010). Intrinsic factors are typically those which predict how an individual will react to the situation-specific extrinsic or ‘enabling’ factors which may precede injury facilitate the manifestation of injury (e.g., training behaviours, sport-specific cultural norms, equipment use; Wiese-Bjornstal, 2010). The associated implications for athlete behaviour and injury vulnerability are therefore based on the subsequent exposures, choices, and hazards present as a result of these interactions.

*Figure 2.* Biopsychosocial sport injury risk profile (adapted from Weise-Bjornstal, 2010).

Risk factors can also be considered as modifiable or non-modifiable (Meeuwisse, 1994; Wiese-Bjornstal, 2010). Modifiable risk factors refer to those that can be altered by injury prevention strategies to reduce injury rates, such as use of protective gear or rule adaptations; while non-modifiable risk factors, which cannot be altered, may affect the relation between modifiable risk factors and injury (e.g., an athlete’s biological characteristics; Caine, Maffulli, & Caine, 2008; Meeuwisse, 1994). Both modifiable and
non-modifiable intrinsic and extrinsic risk factors to concussion have been researched previously (e.g., Abrahams et al., 2014; Kerr, 2014), producing inconsistent results. Some of the non-modifiable intrinsic factors which have been proposed in previous research as possible risk factors to sport-related concussion are genetic predisposition (i.e., some athletes may be genetically predisposed to sustaining a concussive injury from the same magnitude of acceleration (or force) that other people can tolerate without injury); age and gender (specifically, higher concussion rates have been suggested for female athletes and junior populations); and pre-existing psychopathology (i.e., comorbidities such as attention-deficit/hyperactivity disorder (ADHD), migraine headaches, or mood disorders have been suggested to increase the risk of sustaining a concussion, as well as experiencing prolonged recovery). Previously proposed extrinsic risk factors for sport-related concussion have included previous concussive injury; use of protective gear and equipment (e.g., headgear and mouthguards); and playing position and playing style (Abrahams et al., 2014; Kerr, 2014). Coaching style and implementation of rules and refereeing have also been previously suggested as important modifiable extrinsic factors to consider in injury risk analysis, however these factors will not be directly assessed in the present research.

The present research project explored a selection of biopsychosocial factors which have been suggested in previous literature and which may impact an athlete’s risk of sustaining a rugby-related concussion, including modifiable and non-modifiable intrinsic and extrinsic variables. The following three studies aimed to identify and improve understanding of these factors and how they interact to predict concussion incidence in junior rugby union. Each of these studies drew from a sample of 259 junior (11-17 year old) rugby union players, who were recruited from the Sunshine Coast region. As each of the studies address a different aspect of the overall research project, case selection criteria for reported concussions was different for each study. In the first study which considered the antecedents of sport-
related concussion, only medically diagnosed concussions that were sustained during participation in any sporting activity were included in the analyses. This classification was further restricted to rugby-related medically diagnosed concussive injury in the second study as the research question considered the impact of sport-specific behaviours on concussion incidence. All medically diagnosed concussions (i.e., concussive injury sustained during participation of any activity) were included in the analyses of the third study, as the overall consequences of concussion on cognitive and emotional function were investigated in this aspect of the project.

**Study One - Antecedents of Concussion in Junior Rugby Union: A Predictive Analysis of Intrinsic Biopsychosocial Factors**

Individual, or intrinsic, risk factors refer to the biological and psychosocial characteristics which may predispose an athlete to injury, such as physical characteristics or personality traits. Intrinsic characteristics further interact with extrinsic factors (e.g., training methods, equipment) to increase an individual’s risk of injury (McKinlay et al., 2010; Wiese-Bjornstal, 2010). Participating in any contact sport comes with an obvious contextual risk of injury, however much of the research on paediatric sport-related concussion has focussed on the treatment and recovery of the individual rather than understanding the mechanisms unpinning the possible increased susceptibility of junior athletes. The literature exploring the aetiology of sport-related concussion has suggested that concussion incidence may be modulated by a range of intrinsic factors, including an athlete’s age (Gessel et al., 2007; Hollis et al., 2009); physical composition (e.g., physical fitness, musculature, prenatal testosterone exposure; Buzzini & Guskiewicz, 2006; Hönekopp, Manning, & Müller, 2006; Kempel et al., 2005); aggressive or impulsive playing style (Castanier, LeScanff, & Woodman, 2010; Osborn, Blanton, & Schwebel, 2009); and premorbid psychological functioning (Grady, 2010). The individual impact of each of these intrinsic variables on
concussion incidence and possibly experiencing ongoing post-concussion complications remains inconclusive (see Abrahams et al., 2013 for review). The assessment of a player’s complete biopsychosocial profile may therefore be useful in predicting the antecedents to sport-related concussive injuries in junior rugby.

**Biological Factors**

Given the notable physical and hormonal changes occurring throughout adolescence, there is justifiable reason to consider salient intrinsic biological factors that may influence an athlete’s incidence of sport-related concussion. For example, the adolescent growth spurt has been attributed to increased risk of sport-related head injury due to their rapid changes in body composition, musculature, competitiveness, and overall physical ability (Caine, Maffuli, & Caine, 2008).

**Age.** The interaction between age and concussion incidence is largely contentious in research on sport-related head injury. Research that has investigated age as an antecedent of sport-related concussion has produced inconclusive results, however there has been a stronger focus on treatment and recovery in paediatric and adolescent concussion literature rather than understanding the mechanisms unpinning concussion risk in this population. Several studies have found that older athletes had a higher incidence of concussion than their younger counterparts (e.g., Gessel et al., 2007; Hollis et al., 2009; Makdissi et al., 2013). Gessel and colleagues (2007) suggested that higher rates of concussion in older athletes may be due to a greater game speed and intensity in style of play, leading to more concussive impacts. Similarly, Hollis and colleagues (2009) found that higher rates of concussion were reported when skill level and fitness were highest, as well as when player size, strength, aggression, and competitiveness were also increased.

The inverse interaction has also been found with numerous studies finding younger athletes to be significantly more at risk of sustaining a concussion than older athletes (e.g.,
Cohen et al., 2009; Guskiewicz et al., 2004; Hasler, Carmont, & England, 2010; McKeever & Schatz, 2003). This increased incidence of concussive injury in younger players has been attributed to aspects of adolescent physiology and development, including decreased myelination in the prefrontal cortex (as discussed in chapter two) and physical differences of athletes in different stages of puberty (e.g., head-to-body ratio, fitness level, body mass, neck musculature; Buzzini & Guskiewicz, 2006; Cohen et al., 2009; McKeever & Shatz, 2003). In terms of possible explanations of these equivocal results, low statistical power (Hasler, Carmont, & England, 2010), inconsistent injury definitions (Cohen et al., 2009; Hollis et al., 2009), variable populations (e.g., sport specific versus different sports), and uncontrolled confounding variables such as player exposure and use of protective gear are all contributing factors to the disagreement regarding the impact of age on concussion incidence. It is important to note that research into sport-related concussion is made difficult by underreporting, especially in adolescent athletes (MCrea et al., 2004). Although the precise interaction between an athlete’s age and their susceptibility to concussive injury in sport remains uncertain, each of the formal management guidelines (e.g., International Rugby Board, Zurich Consensus Guidelines) propose junior athletes as being an ‘at risk’ population (IRB, 2014; McCrory et al., 2013).

**Pre-injury physical characteristics.** The mental health benefits of regular physical exercise are widely accepted across many domains. The protective qualities of physical exercise and physical fitness against brain inflammation and degradation are also well known (e.g., see Cotman, Berchtold, & Christie, 2007 for review), however only relatively recently have been applied to the treatment of sport-related concussion. Following a concussive injury, a cascade of pathophysiological events are activated, leading to possible tissue damage (e.g., oxidative stress, apoptosis, and inflammation; Archer, Svensson, & Alricsson, 2012; Lenz, Franklin, & Cheadle, 2007). The impact of physical exercise in concussion
management ranges from anti-apoptotic effects to the augmentation of neuroplasticity (Ang & Gomez-Pinilla, 2007) and diminishes cerebral inflammation by elevating agents involved in immune function, and reinforces glial cells and blood–brain barrier intactness (Archer, Svensson, & Alricsson, 2012).

A review of literature showed that much of the research on the benefits of physical fitness has been focussed on neuro-rehabilitation following concussion rather than the possible predictive value of pre-injury physical conditioning on concussive injury susceptibility (e.g., Collins et al., 2014; Gagnon et al., 2009; Silverberg & Iverson, 2013). However it has been proposed that athletes with low pre-injury physical fitness may become more easily fatigued during game play, inhibiting their ability to react effectively to the demands of the dynamic game environment thus indirectly increasing their risk of injury (Kontos, Elbin, & Collins, 2005). Furthermore it has been suggested that underdeveloped or weaker musculature (especially in the neck and shoulders) may impair the dissipation of force experienced during a collision, increasing the impact and/or impulse load on the brain (Buzzini & Guskiewicz, 2006). Body mass has also been associated with incidence of sport-related concussion, specifically Hollis et al. (2009) identified a linear relationship between concussion incidence and rugby players’ height and weight. Despite age related physical changes being identified as possible factors contributing to an athletes’ risk of injury (as discussed above), the interaction between an athlete’s level of pre-injury fitness and concussion incidence has not been adequately researched.

**Prenatal testosterone exposure.** Testosterone has long been acknowledged as a salient hormone involved in sporting behaviour and achievement (Bardin & Catterall, 1981; Manning & Taylor, 2001); furthermore, the impact of testosterone begins during gestation. A suggested correlate of prenatal testosterone is the ratio measurements of the second (index finger) and the forth (ring finger) digits (2D:4D; Hönekopp, Manning, & Müller, 2006).
Research suggests that while testosterone promotes prenatal growth of the fourth digit, oestrogen stimulates the growth of the second digit, therefore a low 2D:4D is indicative of a uterine environment higher in testosterone than oestrogen (i.e., when 4D is longer than 2D the lower ratio is indicative of greater prenatal testosterone exposure).

The 2D:4D ratio has been found to be sexually dimorphic with lower ratios in males compared to females (Hönekopp, Manning, & Müller, 2006; Manning & Taylor, 2001; Neave, Laing, Fink, & Manning, 2003; Tester & Campbell, 2007). In a study by Manning and Taylor (2001) prenatal testosterone exposure was found to be significantly associated with sporting achievement in men. The length of the right and left second and fourth digits of 304 professional male soccer players were photocopied and measured from the crease proximal to the palm to the tip of the digit. The athletes in the sample included junior club players from different divisions (i.e., Division I, II, or III), coaches who had previously played professionally, elite international representatives, and a control group. An overall increase in 2D:4D was observed, in sequence, from the elites, coaches, and players. The mean 2D:4D ratio was also found to be lower in athletes compared to controls, indicating that athletes experienced greater prenatal testosterone exposure (Manning & Taylor, 2001).

Furthermore, men with low 2D:4D ratio tended to have a higher mental rotation scores compared to men with high 2D:4D, providing support for the proposition that testosterone promotes the growth of the right hemisphere and facilitates visual-spatial ability (Kempel et al., 2005; Manning & Taylor, 2001).

Digit span ratio has also been examined in relation to other noted sporting proficiencies such as physical fitness (Hönekopp, Manning, & Müller, 2006); risk taking behaviour (Hönekopp, 2011); physical aggression (Bailey & Hurd, 2005); cognitive ability and problem solving (Austin, Manning, McInroy, & Mathews, 2002); and perceived dominance and masculinity (Neave et al., 2003). Training intensity and frequency have also
been found to be negatively correlated with 2D:4D, suggesting that prenatal testosterone exposure may increase an athlete’s overall competitiveness (Hönekopp, Manning, & Müller, 2006). The interaction between prenatal testosterone exposure and concussion incidence has never been directly investigated. Based on the findings of the above studies, it can be hypothesised that a lower 2D:4D ratio may be associated with lower incidence of concussive injury. Athletes with greater physical fitness, spatial awareness, mental rotation, and problem solving ability may be more able to navigate rough game play, avoiding head impact and subsequent concussion. Conversely, the higher perceived dominance, physical aggression, and risk taking that has also been associated with low 2D:4D ratio scores may increase athletes’ incidence of concussion as these characteristics are cornerstones of competitive game play.

Psychological Factors

Adolescents have been found to be more vulnerable to the effects of concussion, and may experience ongoing and persistent disruptions to neuropsychological and executive functioning (Baillargeon et al., 2012; Howell et al., 2013; Iverson et al., 2005). Due to the ongoing myelination of axons in the prefrontal cortex throughout adolescence, cognitive functions associated with this region are still developing (e.g., cognitive flexibility, executive function, learning and memory; Blakemore & Choudhury, 2006; Iverson et al., 2005). This is important to consider when assessing the impact of intrinsic psychological characteristics on concussion incidence, especially in regards to symptomatic expression and neurocognitive disruption which may be ubiquitous with characteristics of typical adolescent development (e.g., impulsivity, changes in mood, delayed cognition).

Impulsivity and risk taking. Risk taking behaviour may also play a significant role in determining concussion incidence among adolescents who play contact sport, especially in games such as rugby in which activities such as tackling and scrumming for possession
require some physical risk (e.g., intercepting an opponent, diving for the ball). In a study exploring the characteristics of male athletes who take risks in sport Castanier, LeScanff, and Woodman (2010) found that men with a personality low in conscientiousness combined with high extroversion (i.e., impulsive, hedonistic) were greater risk-takers. Similarly, findings from a prospective study of professional athletes ($M = 27.39$ years, $SD = 3.59$) supported the theory that sensation seeking athletes may be more likely to take risks and place themselves in potentially dangerous situations more often than athletes who are not prone to sensation seeking (Osborn, Blanton, & Schwebel, 2009). This was observed in a sample of nonprofessional rugby union players, with more impulsive athletes reporting a higher incidence of concussion compared to players who reported low to medium impulsivity scores (Hollis et al., 2009).

Although research exploring the impact of personality traits such as impulsivity and risk taking on concussion incidence in junior sport is limited, previous paediatric research has found children with high scores of extraversion and impulsivity, and low scores of self-control have increased incidence of both minor and daily injuries (Schwebel & Barton, 2006). In an early study by Morrongiello and Rennie (1998) investigating the impact of risk-taking behaviour on injury in children ($M = 9.39$ years) individuals who exhibited more risk-taking behaviours were found to attribute injury more to ‘bad luck’ than to their own actions. In an adolescent sample, Kontos (2004) found that perceived invulnerability and over-estimation of sporting skill was more strongly associated with injury susceptibility. Given the known implications of frontal lobe development during adolescence and the emergence of egocentrism (discussed in chapter two), the increase in risk taking and impulsivity (i.e., inadequate planned behaviours) during this developmental stage may act as an antecedent to concussive injury in contact sport participation.
**Pre-injury psychological functioning.** Throughout the progression from late childhood and adolescence there are considerable neurobiological and psychological transitions occurring (see chapter two). During this developmental stage emotional responses have not yet consolidated, thus premorbid conditions, such as depression, anxiety, and other mood disorders, are recognised as influential variables when evaluating concussed athletes (Grady, 2010). While the mechanisms of this interaction are poorly understood, Grady (2010) proposes that individuals with pre-morbid disorders have less ‘reserve’, leaving them less able to compensate for the disruptions caused by concussion. The literature on comorbidities and sport-related concussion in adolescence is scant. The signs and symptoms of concussion are similar to those experienced in depression, anxiety, attention-deficit and learning disorders, and cognitive delays, thus identifying concussion in this population can be difficult (Fay et al., 2010; Grady, 2010; Halstead & Walter, 2010). There have been a few studies in which pre-morbid cognitive ability significantly moderated the outcomes of concussion in children and adolescents (e.g., Fay et al., 2010). However in the majority of the literature, children with known learning or behaviour problems are omitted from concussion studies, despite non-injury related risk factors being identified as possible predictors of injury (Fay et al., 2010; Grady, 2010).

**Sociocultural Factors**

Sociocultural influences and attitudes towards injury are often overlooked in the epidemiological study of sport-related concussion, despite the clear hyper-masculine subculture often held in most contact sports including rugby. The cultural norms in contact football - which can by typified by slogans such as “no-pain-no-gain” and “man up” - potentially create environments of increased injury risk, consequent of the shared ethos of “play through the pain”, “putting the team first”, and “giving 110%” (Tibbert, Andersen, & Morris, 2015). In regards to understanding the antecedents to sport-related concussion in
adolescence, the possible influence of the ‘real men play rugby’ attitude should be considered.

Directly evaluating this collective attitude is complicated by the processes of enculturation (i.e., an individual's identification and continual engagement in the beliefs, values, and behaviours of their own culture), and acculturation (i.e., the transition into a subcultures through processes of assimilation and compromise of personal beliefs, values, and behaviours; Tibbert, Andersen, & Morris, 2015). This is illustrated in the differential understanding of ‘mental toughness’ that exists between members from within the rugby subculture and those who are not. For example, a rugby player may not see the issue in returning to play and just ‘getting on with it’ following a head impact; while a media reporter may see the same behaviour as imprudent recklessness. Through socialisation experiences young athletes are especially likely to succumb to the conscious and unconscious pressure to conform to the values and ideals of their sporting culture to gain peer acceptance, as they are still developing and consolidating their identities (Gucciardi, Gordon, Dimmock, & Mallett, 2009; Tibbert, Andersen, & Morris, 2015). Athletes learn and adopt the expectations and norms of their sport subcultures from perceived authority figures, such as coaches and role models (Connaughton & Hanton, 2009; Wiese-Bjornstal, 2010). Therefore the need to assess intrinsic sociocultural factors such as duration of exposure (i.e., how long the athlete has been involved with rugby), as well as family involvement (i.e., whether other members of the family also participate), is fundamental to better understanding the subcultural dogma and learned behaviours which may influence an adolescents’ incidence of concussion.

Research Aims

Past literature has suggested possible links between individual (intrinsic) factors and sport-related concussion incidence, however methodological discrepancies (e.g., inconsistent injury definition, non-generalisable populations) in addition to a general focus on treatment
rather than prevention has led to an inconsistent and scattered understanding of the issue. Through the comprehensive assessment of individual variables within a multi-measure cross-sectional research design, the current study aimed to better inform the possible antecedents of sport-related concussion in junior contact sport. Taking a biopsychosocial approach to the complex issue of sport-related concussion contextualises the individual factors associated with the injury. That is, it considers the biological, psychological, and sociocultural variables which may impact concussion incidence in junior rugby union. By concurrently exploring intrinsic biopsychosocial variables including players’ age, physical build, and prenatal testosterone; impulsivity and cognitive function; and social factors (e.g., duration of participation, immediate family involvement) this study aimed to investigate which intrinsic attributes contribute to increased concussion incidence in junior rugby while controlling for covariance between predictor variables. Specifically it was hypothesised that healthier biological variables (e.g., age appropriate BMI and aerobic fitness) would be predictive of lower incidence of concussion, while maladaptive psychological and social functioning would be predictive of higher incidence of concussion.
Method

Participants

Participants were male junior rugby union players recruited from community clubs throughout the Sunshine Coast region. This cross-sectional cohort study consisted of 259 participants (55% response rate) who were enrolled and actively participating in age-defined teams ranging from under 11- to under 17- year olds. Participants were approached through their local clubs, and data was collected during mid-season training from June to August. Eight of the 11 Sunshine Coast junior rugby union clubs agreed to participate in the present study with 33 teams in the eligible age groups (11-17 year old males; $M = 13.0$, $SD = 1.8$). More participants identified playing primarily in a forward position (i.e., Hooker, Prop, Lock, Flanker, or Eight) than in a back position (i.e., Halfback, Five-Eight, Centre, Wing, or Fullback), 52.9% and 43.2% respectively. The remaining players identified as having more than one position.

Measures

Health and fitness. Height and weight measures were taken for each athlete to calculate their body mass index (BMI; weight in kilograms divided by squared metres of height; National Health and Medical Research Centre [NHMRC], 2013). Height measurements were taken using a standard stadiometer while the participants were barefoot and facing directly forward (i.e., away from the slide ruler on the stadiometer). A digital weight scale was used to weigh each participant, who remained barefooted and in normal training clothes. Height and weight measures were both recorded to two decimal points. Participants’ aerobic fitness was assessed using a multi-stage 20 metre shuttle run (i.e., Beep Test), which is widely used and valid measure of VO$_2$ max (Leger, Mercier, Gadoury, & Lambert, 1988). The 20 metre shuttle run test is a reliable measure for use in both child ($r = 0.89$) and adult ($r = 0.95$) populations, with significant test-retest reliability ($p = <.05$; Leger
et al., 1988). Participants are instructed to run between two markers set 20 metres apart, keeping pace with a pre-recorded tone. The pace increases by 0.5 km/h each minute as the test progresses through the 21 stages, which consist of eight to 15 laps within each stage. The test concludes when the individual is no longer able to reach the line before the tone, awarding the last announced stage as the participant’s score. This test was run on the football field surface and participants were instructed to wear their normal football boots to facilitate consistency between all participants in the study. Each of these measures were taken during each team’s regular scheduled football training after the athletes had warmed up. Each participants’ scores were compared against age-banded national averages (NHMRC, 2013; Olds, Tomkinson, Leger, & Cazola, 2006).

**Prenatal testosterone exposure.** A high resolution portable flatbed scanner was used to take digital scans of each participant’s lightly pressed palms to estimate their level of prenatal testosterone exposure. Participants were instructed to place their palm flat against the glass of the scanner, which was then covered by a dark sheet and lightly pressed by the researcher to ensure participants’ fingers were flat against the scan bed. Scans of both the left and the right palm were taken so an average ratio could be calculated. Each scan was then printed in high definition and the length of the second and fourth digit (i.e., from the tip of the finger to the crease proximal to the palm) was quantified using a millimetre measure for each hand. These measurements were calculated as an average ratio (sum of left and right hand ratios, divided by two), with lower measurements indicating greater prenatal testosterone exposure.

**Demographic information.** Demographic information was collected using both self-report and parental-report questionnaires which included questions regarding the athlete’s age, level of schooling, average grades, and involvement in other sports (see appendices 1 to 3). Questions regarding the athlete’s rugby involvement included how long they had been
participating, how many hours they spend training, and whether other members of their family play rugby also were included. Details of any previous concussions were asked in both the athlete- and parent-report surveys, encompassing both rugby related and general concussive injuries. Participants were asked to identify whether they had ever sustained a concussion, which was defined as “temporary impairment or disruption to brain function caused by any knock to the head, face, neck or body”. Additionally, participants were asked to indicate which symptoms of concussion they experienced from a list (which was adapted from the CIS guidelines; McCrory et al., 2013). Only concussive injuries sustained during participation in sport, as diagnosed by medically trained personnel were included in the final analyses. Parents were also asked about their child’s existing conditions (e.g., learning difficulties, ADHD) and whether they took regular medication. Inter-rater reliability was assessed for self- and parental report data. No significantly divergent responses occurred in this sample, with most responses being strongly correlated between respondents (r ranging from .84 to .91, p <.01).

**Psychological variables.** Deficits and strengths in social-cognitive development were assessed using the 25-item self-report Strengths and Difficulties Questionnaire (SDQ; Goodman, Meltzer, & Bailey, 1998). The SDQ is a brief screening measure that is being employed increasingly for the purpose of identifying behavioural and emotional problems in children and adolescents in multiple clinical and non-clinical samples. The SDQ measures behavioural and emotional functioning on five 5-item subscales; conduct problems, hyperactivity, emotional problems, peer problems, and pro-social behaviour. This measure had moderate internal consistency within each of the subscales (Cronbach’s alpha [α] coefficients ranged from .61 for peer problems, to .64 for the total social difficulties). The SDQ has demonstrated consistent discriminant validity between clinical and non-clinical populations in both children (8-13 years old) and adolescents (11-16 years old; Muris,
Meesters, Eijkelenboom, & Vincken, 2004; Goodman, Meltzer, & Bailey, 1998). Cross-informant correlation (mean Cronbach’s α = 0.34) and retest stability after 4 to 6 months (mean Cronbach’s α = 0.62) has also been consistently valid in 5 to 16 year old non-clinical populations (Goodman, 2001).

The Revised Children’s Anxiety and Depression Scale (RCADS; Chorpita et al., 2000) was used to evaluate participants’ emotional functioning. This 47-item measure is an adaptation of the Spence Children's Anxiety Scale (SCAS; Spence, 1997) intended to assess children's report of symptoms corresponding to selected DSM-IV anxiety disorders and depression. The adapted measure includes subscales for separation anxiety, social phobia, generalized anxiety, panic disorder, obsessive compulsive disorder, and major depressive disorder. Test-retest reliability has been found to be favourable for each of the RCADS subscales, in addition to strong structural, convergent, and discriminant validity in 8 to 18 year old populations (Chorpita et al., 2000). This measure was found to have strong internal consistency within each of the subscales (α = .95).

Athletes’ attentional, motor, and non-planning impulsiveness was assessed using the self-report, 8-item brief version of Barratt’s Impulsiveness Scale (BIS-Brief; Steinberg, Sharp, Stanford, & Tharp, 2012). Reliability estimates for the BIS-Brief were high (α = .89) for this sample, and the measure has been found to have consistent discriminant validity in clinical and non-clinical adolescent populations (13-22 year olds; M = 16.72, SD = 2.36; Steinberg et al., 2012). Each of these self-report Likert-scale questionaries were completed by the participants at home and returned to the research team by mail.

**Executive function.** Executive function was measured using the parent report version of the Behaviour Rating Inventory of Executive Function (BRIEF-PR; Gioia, Isquith, Guy, & Kenworthy, 2000). This is an 86-item paper-and-pencil questionnaire which evaluates the emotional, behavioural, and metacognitive skills (broadly described as
executive abilities. This questionnaire uses a three-point scale, with possible responses including ‘Never’, ‘Sometimes’, and ‘Often’. The BRIEF-PR is an ecologically valid measure of the manifestations of EF in daily life, such as impact on school, family functioning, and social relationships, and is widely used in EF assessments of child and adolescent development (Gioia et al., 2000). The BRIEF-PR has been used to evaluate the executive functions of children and adolescents presenting with a wide range of concerns, both non-clinically and clinically (e.g., in child and adolescent populations diagnosed with attention deficit/hyperactivity disorder, autism spectrum disorder, and traumatic brain injury (Gioia et al., 2000).

An overall index of executive dysfunction is provided by the Global Executive Composite (GEC), which is comprised of two subordinate indices called the Behavioural Regulation Index (BRI) and the Metacognition Index (MCI). The BRI is comprised of three subscales, including ‘Inhibit’ (e.g., delay or stop impulsive behaviours), ‘Shift’ (e.g., change tasks and adapt to new situations) and ‘Emotional Control’ (e.g., modulate mood appropriately). The MCI is comprised of five subscales, including ‘Initiate’ (e.g., generate ideas, start new tasks), ‘Working Memory’ (e.g., sustain one’s focus, keep information in mind), ‘Plan/Organise’ (e.g., think prospectively, follow a plan), ‘Organisation of Materials’ (e.g., clean-up after oneself), and ‘Monitor’ (e.g., check one’s work for errors, monitor the effect of one’s behaviour on other people). Item scores are computed as $T$ scores, which are then compared against normative data, which also provides percentile ranking and 90% confidence interval values for each scale by gender and for four age groupings (i.e., 5 to 7 year olds, 8 to 10 year olds, and 14 to 18 year olds). The BRIEF-PR has been found to have a Cronbach’s $\alpha$ coefficient measure of internal consistency ranging from .80 to .98 for clinical and normative samples, respectively (Gioia et al., 2000). This measure had a strong reliability alpha of .95 for this sample. A high test-retest reliability correlation across each of
the scales (mean $r = .81$) has also been found for this measure after an average interval of two weeks. In the non-clinical sample, BRI, MCI, and GEC retest correlations were .84, .88, and .86 respectively (Gioia et al., 2000).

**Procedure**

Ethical approval for this study was granted by the Sunshine Coast University Human Research Ethics Committee (S/14/662). Support was sought from the district rugby coordinators (Sunshine Coast Stingrays) before the coaches of individual teams were contacted. Participants were approached by the research team during their weekly training sessions at their home field, where the aim of the study and participation details were explained. Athletes who wished to participate in the study were given an information pack to take home; this included an information sheet (see appendix 4) and consent form as well as the demographic and psychometric questionnaires for both themselves and their parents/guardians to complete. The following week, athletes who had returned their consent forms (either by mail or directly to the research team) had their biometrics measured and their left and right hands digitally scanned. Following a brief warm up (conducted by the team coach), athletes completed the beep test as a team (up to 15 players simultaneously) at the beginning of their regularly scheduled training session. Questionnaires completed by both the athlete and their parent/guardian were returned to the research team either in person or via Australia Post in the reply paid envelopes that were provided. Questionnaires that were at least 80% complete were included in analysis; respondents who did not return both the athlete and parent report questionnaires were excluded from the study ($n = 2$). Once both physical and written data had been collected and matched to the participant, data were de-identified prior to analysis.
Results

Concussion History

Twenty-nine percent \( (n = 75) \) of the sample reported that they had sustained a medically diagnosed concussion. Team medics (55.6%), family doctors/general practitioners (25.9%), and hospital/emergency room (16.7%) were most frequently identified as the sources of these diagnoses. Over 81% of the concussive injuries reported were sustained while participating in sport \( (n = 60) \), 76% of which were sustained while playing rugby \( (n = 56) \); other causes of injury were accidents such as slips and falls (16%) and motor vehicle accidents (4%). Reported concussions that were not related to injuries sustained during sporting participation \( (n = 15) \) were excluded from this study. Over half of the sample (53.3%; \( n = 32 \)) reported having experienced only a single sport-related concussion; 28.3% \( (n = 17) \) reported having a history of two concussions; 15% \( (n = 9) \) reported a history of 3-4 concussions; and the remaining 3.4% \( (n = 2) \) reported having sustained five or more sport-related concussions. Athlete and parent reports of concussion were strongly correlated \( (r = .91, p < .01) \). IBM SPSS Statistics for Windows, version 22.0 was used to calculate each of the following analyses.

Assessment of the Biopsychosocial Model

The biopsychosocial model comprises a large array of variables in this study, including athletes’ age, BMI, aerobic fitness, prenatal testosterone ratio, impulsivity, behavioural and emotional functioning, depression and anxiety, executive function, duration of participation, their involvement with other rugby teams as well as in other sports, and whether other members of their immediate family also participate in contact sport. To assess the predictive value of the entire model a logistic regression was performed, with concussion history as the binary dependent variable (i.e., 1 = participant has sustained a medically diagnosed concussion; 0 = no concussion history). This model explained 22.7% of the
variance in sport-related concussion incidence ($R^2 = .227$). The Hosmer and Lemeshow was non-significant indicating goodness of fit and hence no significant discrepancy between observed and predicted concussion risk ($\chi (8) = 15.0$, $p = .06$). Overall the model was non-significant ($\chi (17) = 25.9$, $p = .08$). Assessing all the elements of the entire model at once means that the number of included variables in the model was excessive given the sample size and hence assessment of the model’s significance was affected by restricted power, possibly leading to a Type II error. In order to more fully understand the most important elements of each domain of the model it was decided to run separate logistic regressions for each domain separately to circumvent these power issues.

**Assessment of the Biological Domain of the Biopsychosocial Model**

Inter-correlations for the independent biological variables are displayed in Table 4. The mean height of the sample was 160.9 centimetres ($SD = 13.4$); and weight was 55.1 kilograms ($SD = 16.5$); giving a mean body mass index of 20.8 ($SD = 3.7$) for the sample, which is within the ‘average’ range (BMI = 14.6 – 22) as defined by the NHMRC (2013). The average beep test score for the sample was 8.2 ($SD = 2.1$), which is considered as ‘average’ for this age group (6.5-8.8; NHMRC, 2103; Olds et al., 2006). The combined left and right hand average 2D:4D ratio measure for the sample was .96 ($SD = .03$), which is comparable to the national average for Australian males ($M = .97$, $SD = .03$; Loehlin et al., 2006). To allow for comparison against national norms, participant data was categorised into two age groups, 11 to 13 years ($n = 159$; mean age = 11.7, $SD = 1.0$) and 14 to 17 years ($n = 100$; mean age = 14.9, $SD = .9$).

The mean physical composition for 11 to 13 year olds was 154.1 centimetres in height ($SD = 11.0$) and 47 kilograms in weight ($SD = 10.5$), giving a BMI of 19.6 ($SD = 2.9$). Compared to national averages (NHMRC, 2013), the majority of the 11-13 year old athletes (79.9%, $n = 119$) had an ‘average’ BMI percentage (BMI = 15 - 22); 16.8% ($n = 25$) were
‘overweight’ with a BMI in the 85\textsuperscript{th} percentile (ranging from 22.1-25.5); and 3.4\% (n = 5) 11 to 13 year olds had a BMI in the 95\textsuperscript{th} percentile (>25.6), placing them in the ‘obese’ category. The beep scores for the 11-13 year olds (M = 7.7, SD = 2.0) were relatively evenly distributed between ‘below average’ (<6.4), ‘average’ (6.5-8.8), and ‘above average’ (>8.9) performance (27.9\%, 40.4\%, and 31.6\%, respectively).

Table 4. Inter-correlations of individual biological variables and SR concussion

<table>
<thead>
<tr>
<th></th>
<th>N = 259</th>
<th>M</th>
<th>SD</th>
<th>Age</th>
<th>Beep score</th>
<th>Height (cms)</th>
<th>Weight (kgs)</th>
<th>BMI</th>
<th>2D:4D</th>
</tr>
</thead>
<tbody>
<tr>
<td>SR concussion history</td>
<td>†</td>
<td>†</td>
<td>.34**</td>
<td>.16*</td>
<td>.20**</td>
<td>.21**</td>
<td>.17*</td>
<td>-</td>
<td>-.03</td>
</tr>
<tr>
<td>Age</td>
<td></td>
<td>13.0</td>
<td>1.8</td>
<td>-</td>
<td>.373**</td>
<td>.775**</td>
<td>.710**</td>
<td>.463**</td>
<td>.176**</td>
</tr>
<tr>
<td>Beep score</td>
<td></td>
<td>8.2</td>
<td>2.1</td>
<td>.373**</td>
<td>-</td>
<td>.217**</td>
<td>-.032</td>
<td>-.245**</td>
<td>-.052</td>
</tr>
<tr>
<td>Height (cms)</td>
<td></td>
<td>160.9</td>
<td>13.4</td>
<td>.775**</td>
<td>.217**</td>
<td>-</td>
<td>.815**</td>
<td>.444**</td>
<td>.104</td>
</tr>
<tr>
<td>Weight (kgs)</td>
<td></td>
<td>55.1</td>
<td>16.5</td>
<td>.710**</td>
<td>-.032</td>
<td>.815**</td>
<td>-</td>
<td>.870**</td>
<td>.181**</td>
</tr>
<tr>
<td>BMI</td>
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<td>.463**</td>
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</tr>
<tr>
<td>2D:4D</td>
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<td>.96</td>
<td>.03</td>
<td>.176**</td>
<td>-.052</td>
<td>0.104</td>
<td>.181**</td>
<td>.193**</td>
<td></td>
</tr>
</tbody>
</table>

*Means and SD not available for binary variables. * Correlations are significant at the .05 level (2-tailed); ** Correlations are significant at the .01 level (2-tailed).

The mean physical composition for 14 to 17 year olds was 173.2 centimetres in height (SD = 7.5) and 69.4 kilograms in weight (SD = 15.6), giving a BMI of 23 (SD = 4.0).

Within the 14-17 year old age group, 68.3\% (n = 56) of athletes were considered of ‘average’ weight (BMI = 16-24); 24.4\% (n = 20) were considered ‘overweight’ (BMI = 24.1-27.8); and 7.3\% (n = 6) had a BMI in the 95\textsuperscript{th} percentile (>27.8), placing them in the ‘obese’ category (NHMRC, 2013). A third of the older age group scored below the national average for their age group on the ‘beep’ test (<8.2); 53.8\% were within the ‘average’ performance range (8.3-11.3); and the remaining 12.8\% scored ‘above average’ (>11.4; M = 9.1, SD = 2.2).

**Logistic regression.** A logistic regression was conducted to examine the elements of the biological domain of the biopsychosocial model on the incidence of concussion (history
of concussion versus no history of concussion). These elements included athlete age, BMI, aerobic fitness, and prenatal testosterone on the likelihood of sustaining a concussion. In combination, the model for athletes’ biological variables explained 14.1% of variance in concussion incidence (Nagelkerke $R^2 = .141$). The Hosmer and Lemeshow was non-significant indicating goodness of fit and hence no significant discrepancy between observed and predicted concussion incidence ($\chi (8) = 2.8, p = .95$). Overall the model was significant ($\chi (4) = 19.7, p = .01$). This model had a stronger negative predictive value (i.e., this model more strongly predicted the absence of concussion), achieving an overall percentage accuracy of 80.7%. Increasing age was the only biological variable to significantly contribute to the model, with older athletes (14-17 years old) 1.35 times more likely to report concussion than younger athletes (11-13 years old; $ExpB [1.01, 1.81] = 1.35, SE = .15, Wald = 3.96, p = .04$).
Table 5. Inter-correlations of individual psychological variables and SR concussion

<table>
<thead>
<tr>
<th></th>
<th>BIS-Br</th>
<th>SDQ - Prosocial</th>
<th>SDQ Total</th>
<th>RCADS Depression</th>
<th>RCADS Anxiety</th>
<th>BRIEF BRI</th>
<th>BRIEF MCI</th>
<th>BRIEF GEC</th>
</tr>
</thead>
<tbody>
<tr>
<td>SR concussion history</td>
<td>†</td>
<td>†</td>
<td>.01</td>
<td>.01</td>
<td>-.03</td>
<td>-.02</td>
<td>-.11</td>
<td>-.04</td>
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<tr>
<td>BIS-Br Total</td>
<td>16.6</td>
<td>(3.8)</td>
<td>-</td>
<td>.224**</td>
<td>.539**</td>
<td>.336**</td>
<td>.248**</td>
<td>.438**</td>
</tr>
<tr>
<td>SDQ Prosocial</td>
<td>1.2</td>
<td>(1.3)</td>
<td>.224**</td>
<td>-</td>
<td>.538**</td>
<td>.266**</td>
<td>.284**</td>
<td>.247**</td>
</tr>
<tr>
<td>SDQ Total</td>
<td>9.6</td>
<td>(4.7)</td>
<td>.539**</td>
<td>.538**</td>
<td>-</td>
<td>.625**</td>
<td>.614**</td>
<td>.452**</td>
</tr>
<tr>
<td>RCADS Depression</td>
<td>44.2</td>
<td>(10.6)</td>
<td>.336**</td>
<td>.266**</td>
<td>.625**</td>
<td>-</td>
<td>.714**</td>
<td>.259**</td>
</tr>
<tr>
<td>RCADS Anxiety</td>
<td>42.5</td>
<td>(10.3)</td>
<td>.248**</td>
<td>.284**</td>
<td>.614**</td>
<td>.714**</td>
<td>-</td>
<td>.220**</td>
</tr>
<tr>
<td>BRIEF BRI</td>
<td>50.3</td>
<td>(10.1)</td>
<td>.438**</td>
<td>.247**</td>
<td>.452**</td>
<td>.259**</td>
<td>.220**</td>
<td>-</td>
</tr>
<tr>
<td>BRIEF MCI</td>
<td>52.3</td>
<td>(10.4)</td>
<td>.529**</td>
<td>.171**</td>
<td>.440**</td>
<td>.261**</td>
<td>.199**</td>
<td>.641**</td>
</tr>
<tr>
<td>BRIEF GEC</td>
<td>51.7</td>
<td>(10.6)</td>
<td>.530**</td>
<td>.213**</td>
<td>.466**</td>
<td>.297**</td>
<td>.239**</td>
<td>.831**</td>
</tr>
</tbody>
</table>

† Means and SD not available for binary variables. * Correlations are significant at the .05 level (2-tailed); ** Correlations are significant at the .01 level (2-tailed).
Assessment of the Psychological Domain of the Biopsychosocial Model

Inter-correlations for independent psychological variables are displayed in Table 5.

**Descriptive statistics.** The mean scores for all psychological measures were within normal ranges (see Table 6). Means for the BIS-Brief followed a normal distribution (skewness = .18; kurtosis = -.27). SDQ subscale means were all within the ‘normal’ range, except for ‘Conductivity Difficulties’ mean which was ‘borderline’ ($M = 4.5$), indicating low grade clinical presentation of social conductivity problems. Raw scores for the RCADS and BRIEF-PR were converted to T-scores to allow comparison between age groups. T-scores of 50 are considered the normative mean, ± a standard deviation of 10). All of the RCADS and BRIEF-PR means fell within one standard deviation for all sub-scales. Pre-existing diagnoses were reported by 17.5% of participants (e.g., ADHD, learning difficulties, anxiety, epilepsy, diabetes), with 14 of these cases requiring regular medication (e.g., Concerta, Ritalin, Ventalin).

**Logistic regression.** To assess the impact of an athlete’s impulsivity, behavioural and emotional functioning, depression and anxiety, and executive functioning on the likelihood of sustaining a concussion, a logistic regression was performed. Model analysis of the measure totals explained 14.6% of variance ($R^2 = .146$), predicting 81.4% of concussion incidence. Hosmer and Lemeshow was non-significant indicating goodness of fit and hence no significant discrepancy between observed and predicted concussion incidence ($\chi^2 (8) = 12.3, p = .14$). Overall the model was non-significant ($\chi^2 (23) = 22.1, p = .51$), with none of the measure totals nor the subscale totals significantly contributing to the model ($p = >.05$).
Table 6. Population means: BIS-Brief, SDQ, RCADS, & BRIEF-PR

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>M</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>BIS-Brief</td>
<td>251</td>
<td>16.63</td>
<td>3.79</td>
</tr>
<tr>
<td>SDQ</td>
<td>258</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Emotional</td>
<td></td>
<td>7.74</td>
<td>1.69</td>
</tr>
<tr>
<td>- Conduct difficulties</td>
<td></td>
<td>4.53*</td>
<td>2.12</td>
</tr>
<tr>
<td>- Hyperactivity</td>
<td></td>
<td>2.05</td>
<td>1.74</td>
</tr>
<tr>
<td>- Peer problems</td>
<td></td>
<td>1.9</td>
<td>1.62</td>
</tr>
<tr>
<td>- Total Difficulties</td>
<td></td>
<td>9.61</td>
<td>4.70</td>
</tr>
<tr>
<td>- Prosocial behaviours</td>
<td></td>
<td>1.17</td>
<td>1.33</td>
</tr>
<tr>
<td>RCADS</td>
<td>254</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- General anxiety</td>
<td></td>
<td>41.16</td>
<td>9.95</td>
</tr>
<tr>
<td>- Panic disorder</td>
<td></td>
<td>46.72</td>
<td>9.91</td>
</tr>
<tr>
<td>- Social phobia</td>
<td></td>
<td>43.73</td>
<td>10.46</td>
</tr>
<tr>
<td>- Obsessive compulsive disorder</td>
<td></td>
<td>42.67</td>
<td>9.26</td>
</tr>
<tr>
<td>- Major depressive disorder</td>
<td></td>
<td>44.22</td>
<td>10.57</td>
</tr>
<tr>
<td>- Total anxiety score</td>
<td></td>
<td>42.49</td>
<td>10.34</td>
</tr>
<tr>
<td>BRIEF-PR</td>
<td>240</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Inhibitory control</td>
<td></td>
<td>51.24</td>
<td>10.49</td>
</tr>
<tr>
<td>- Change tolerance</td>
<td></td>
<td>49.34</td>
<td>10.57</td>
</tr>
<tr>
<td>- Emotional regulation</td>
<td></td>
<td>49.77</td>
<td>9.65</td>
</tr>
<tr>
<td>- Behaviour Regulation Index</td>
<td></td>
<td>50.3</td>
<td>10.14</td>
</tr>
<tr>
<td>- Initiation</td>
<td></td>
<td>50.51</td>
<td>10.21</td>
</tr>
<tr>
<td>- Concentration/Memory</td>
<td></td>
<td>52.88</td>
<td>10.85</td>
</tr>
<tr>
<td>- Planned behaviour</td>
<td></td>
<td>51.53</td>
<td>10.53</td>
</tr>
<tr>
<td>- Organisation</td>
<td></td>
<td>52.05</td>
<td>9.82</td>
</tr>
<tr>
<td>- Self-evaluation</td>
<td></td>
<td>51.69</td>
<td>10.13</td>
</tr>
<tr>
<td>- Meta-Cognition Index</td>
<td></td>
<td>52.26</td>
<td>10.42</td>
</tr>
<tr>
<td>- Global Executive Function</td>
<td></td>
<td>51.67</td>
<td>10.61</td>
</tr>
</tbody>
</table>

Note. *mean outside of ‘normal’ range.
Assessment of the Sociocultural Domain of the Biopsychosocial Model

Inter-correlations for independent psychological variables are displayed in Table 7.

**Descriptive statistics.** On average, athletes had been playing rugby for 4.6 years ($SD = 2.9$). Athletes who played rugby for more than one team ($n = 109, 42.2\%$) played for either their school team (21\%) or the Sunshine Coast Stingrays region representative team (19.8\%). The majority of the participants (77.5\%; $n = 200$) also participated in other forms of sport, namely other codes of football (e.g., rugby league, AFL, soccer; 26.7\%), or another team ball sport (e.g., basketball, volleyball, cricket; 17.1\%). Over half (55.2\%) of the participants had an immediate family member who also participated in contact sport, such as a sibling (84.4\%) or a parent (12.3\%). Rugby union was the most commonly shared sport (82.9\%).

Table 7. **Inter-correlations of individual sociocultural variables and SR concussion**

<table>
<thead>
<tr>
<th></th>
<th>N = 259</th>
<th>$M$</th>
<th>$SD$</th>
<th>Partic (yrs)</th>
<th>Other rugby</th>
<th>Other sport</th>
<th>Family</th>
</tr>
</thead>
<tbody>
<tr>
<td>SR concussion history</td>
<td>†</td>
<td>†</td>
<td>.21**</td>
<td>.20**</td>
<td>-.00</td>
<td>.07</td>
<td></td>
</tr>
<tr>
<td>Participation (years)</td>
<td>4.6</td>
<td>2.9</td>
<td>-</td>
<td>.19**</td>
<td>-.12</td>
<td>.13*</td>
<td></td>
</tr>
<tr>
<td>Other rugby team</td>
<td>†</td>
<td>†</td>
<td>.19**</td>
<td>-</td>
<td>.05</td>
<td>.11</td>
<td></td>
</tr>
<tr>
<td>Other sport</td>
<td>†</td>
<td>†</td>
<td>-.12</td>
<td>.05</td>
<td>-</td>
<td>.09</td>
<td></td>
</tr>
<tr>
<td>Family</td>
<td>†</td>
<td>†</td>
<td>.13*</td>
<td>.11</td>
<td>.09</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>

†Means and SD not available for binary variables. * Correlations are significant at the .05 level (2-tailed); ** Correlations are significant at the .01 level (2-tailed).

**Logistic regression.** A logistic regression was performed to calculate the predictive probability of social variables on concussion incidence, including athletes’ duration of participation, their involvement with other rugby teams as well as in other sports, and whether other members of their immediate family also participate in contact team sport. This model explained 11\% of the variance in concussion incidence ($R^2 = .11; \chi (5) = 19.5, p < .01$), and correctly predicted 78.9\% of reported concussions. Hosmer and Lemeshow test was non-significant, indicating this model had goodness of fit ($r^2 (8) = 3.09, p = .92$).
Duration of participation (i.e., how many months the participant had played rugby for; \( \text{ExpB} [1.00, 1.02] = 1.01, \text{SE} = .01, \text{Wald} = 5.15, p = .02 \)), participation in other teams (\( \text{ExpB} [.25, .88] = .46, \text{SE} = .32, \text{Wald} = 5.96, p = .02 \)), and immediate relation to a family member who also plays contact sport (\( \text{ExpB} [1.02, 1.82] = .96, \text{SE} = .32, \text{Wald} = .02, p = .04 \)) all significantly contributed to this model. Further analysis indicated that duration of participation and participation in other teams were correlated with incidence of concussion (\( r = .18, p = <.01 \) for both). Analysis of variance (ANOVA) showed that concussion incidence was significantly higher for athletes who had played rugby for longer (\( F(2) = 8.28, p = <.01 \)) and who played for more than one rugby team (\( F(2) = 8.38, p = <.01 \)).

**Discussion**

Results of this study demonstrated that the factors which may potentially increase the incidence of sport-related concussion are a complex interaction of intrinsic and extrinsic variables. This study focused on the intrinsic, or internal factors, which influence injury incidence in junior rugby union players (11-17 years old). Following the concurrent analysis of a variety of biopsychosocial variables which had been identified in past studies as potential influences on sport-related concussion incidence, the main finding of this study was that individual variation in concussion incidence was largely unpredictable.

The finding that athlete age was positively correlated with concussion incidence supports the results of previous studies such as Gessel et al. (2007), Hollis et al. (2009), and Makdissi et al. (2013). The proposition that this increase in concussion incidence may be due to the increases in athletes’ physical size, fitness, and game speed associated with development (Gessel at al., 2007; Hollis et al., 2009) was illustrated by the considerable differences in average BMI and fitness observed between pre-adolescent and adolescent participants in this study. Although the mean BMI of 23.0 for 14 to 17 year old athletes was considered within ‘average’ range of the national norms for adolescents, is was 3.4 points
above the mean BMI of the younger players (BMI = 19.6). Furthermore, the substantial standard deviations for mean height and weight within the pre-adolescent (11cms, 10.5kgs) and adolescent groups (7.5cms, 15.6kgs) illustrates significant within-group disparity in physical composition. Additionally, the mean ‘beep’ score for 14 to 17 year olds was 1.3 points above the mean for the younger age group, which represents a one kilometer per hour increase in speed. In combination, these physical differences may partially explain how older athletes were 1.35 times more likely to report a history of concussion. This however, may also be due to the rule changes which are introduced as athletes get older (e.g., the duration of the game, scrum and lineout engagement; IRB, 2014). This interaction should be interpreted with caution however, as the athlete’s age at the time of injury may not be the same as their age at the time of the study (e.g., a 16 year old athlete may have been 12 at the time of injury). Future studies should consider a prospective methodology to address any discrepancies injury chronology.

The hypothesis that individual psychological characteristics would modulate sport-related concussion incidence was not supported as psychological measures for impulsivity, executive function and planned behaviours, anxiety, and depression each failed to emerge as predictors or correlates to concussive injury. Although consistent with previous research (e.g., Osborn, Blanton, & Schwebel, 2009) this finding contradicts large body of literature suggesting that individual psychological variables such as risk taking and executive function are related to incidence for injury in children and adolescents (e.g., O’Jile at al., 2004; Schwebel, 2004; Wiese-Bjornstal, 2010). While this may be due to the homogeneity within the participants (i.e., the mean scores on all psychological measures were within ‘normal’ ranges), it may also be due to notable methodological issues in this area of research. In a critical review Junge (2000) highlighted that existing research concerning psychological factors and sport-related injury employs heterogeneous designs, different evaluation
strategies, and non-discrete samples. This, along with a strong focus on treatment over prevention, may explain the inconsistencies in research and variable understanding of how psychological functioning impacts on concussion incidence.

The finding that duration of participation was a positive predictor of incidence of reported sport-related concussive injury is consistent with previous research (Hollis et al., 2009; Turbeville et al., 2003; Quarrie et al., 2001). It is difficult, however, to discern whether this is due to environmental or sociocultural exposure. In truth, it is probably a combination of both extra playing time as well as sociocultural impact. The present study also found that multiple-team participation also increased an athlete’s incidence of reporting a concussion. Over 40% of participants played for either their school or the regional representatives’ team in addition to their club team. On one hand, it can be proposed that the greater skill development through more frequent and structured training may have a protective effect against sustaining a concussive injury; on the other, the higher level of competition requires athletes to be more competitive and aggressive, which may lead them to engage in more risky game play (Gessel et al., 2007; Hollis et al., 2009).

The psychosocial impact of acculturation on incidence of reported sport-related concussion has not been widely researched, however some studies have demonstrated that athletes feel a pseudo-cultural pressure to ‘play tough’ and downplay injury (Kerr et al., 2014; McCrea et al., 2004; Wiese-Bjornstal, 2010) based on the norms learnt through socialisation with their teammates and modelling from authority figures (Schinke, Hanrahan, & Catina, 2009). In the present study immediate family member participation along with duration of sport participation was found to impact on reported concussion incidence, which may suggest some sociocultural modelling effect in the incidence of sport-related concussion in junior athletes. This interaction needs to be explored more directly in future research.
Conclusion

Individual variability is a considerable challenge in concussion management, and the need for an individualised approach has become an increasing focus in research and practice. The findings of the present study failed to clearly identify a profile for ‘at-risk’ athletes, instead results suggest that concussion in junior rugby is largely haphazard. The absence of a clear predictive model despite the concurrent assessment of the impact of a comprehensive spread of intrinsic biopsychosocial risk factors illustrates the dynamic nature of concussion incidence in junior sport. Further research is needed to explore concussive injury as a process, instead of a collection of static variables. Specifically, consideration should be given to the behaviours athletes engage in to both prevent sustaining a concussion (e.g., use of protective gear), as well as how they respond to and treat concussion.

Limitations. The primary limitation of this study was the use of retrospective information regarding reported concussive injuries. Consequently injury risk could not be assessed, only reported incidence could be considered. As illustrated by the normative means and standard deviations across each of the variable measures, the participant sample in this study was largely homogenous. Although this may have been reflective of the physical, cognitive, and psychosocial benefits of participating in team sport (see chapter three), the assessment of the impact of underlying pathology on concussion incidence was limited. These limitations may be addressed in future research by broadening the sampling criteria to include other team sports. Future studies should also aim to employ a prospective study design to address any temporal limitations which may arise out of using retrospective data.
Study Two - Junior Rugby Players’ Concussion Related Behaviours: Prevention, Protection, and Return-to-Play

Sport-related concussion is an ever-present issue in organised sport, however there has been growing public interest and concern regarding the seemingly increasing incidence of concussion (Caine, Purcell, & Maffulli, 2014; Harmon et al., 2013; McCrory et al., 2013). This increase may be due to improved awareness and detection of concussion, however it may also reflect the number of concussive impacts occurring in sport as athletes are getting bigger, faster, and more competitive (Daneshvar, Nowinski, McKee, & Cantu, 2011).

Recognising and identifying concussion remains one of the biggest challenges in concussion management, despite various strategies and statements that have been published for both sport-specific and general sport-related concussion management guidance (e.g., the CIS [aka., Zurich Guidelines], National Athletic Trainers Association, IRB guidelines). These challenges arise from discrepancies such as the variation in symptomology presentation between different athletes, as well as individual differences in how athletes approach concussion management (e.g., use of protective gear, masking injury, return-to-play attitudes and behaviours). Although the CIS advocates for individualised approach to evaluation, management, and return-to-play - with particular caution used when assessing junior athletes (Aubry et al., 2002; McCrory et al., 2005; 2009; 2013) - this is not based on empirical evidence.

Previous research has suggested that behavioural factors such as playing position, training behaviour, and use of protective gear (i.e., headgear, mouthguard) may lessen an athlete’s risk of sustaining concussion, however, most of these studies have focused on adult, often professional, players (e.g., Bathgate, Best, Craig, Jamieson, 2001). Furthermore, many existing studies on risk factors in junior sport have explored risk of all injury, not concussion
specifically (e.g., Freitag et al., 2015). Consequently the individual extrinsic factors which may modulate sport-related concussion incidence in junior contact sport is largely unknown.

**Playing Position**

One of the most logical extrinsic (i.e., environmental) variables that may impact concussion incidence in junior rugby is the position they play. In a team made up of 15 players, the bigger, heavier, stronger players will typically play in the forward positions, while smaller, faster players will play in the back positions. Findings from the few studies that have looked at the role of playing position on injury incidence in rugby have produced mixed results (e.g., Bathgate et al., 2001; Freitag et al., 2015; Gardner et al., 2014; McIntosh, McCrory, Finch, & Wolfe, 2010). When all rugby-related injury is considered (i.e., including joint, muscle, and skeletal injury, in addition to concussion); forward playing positions are associated with higher rates of injuries, compared to back positions (Bathgate et al., 2001; McIntosh et al., 2010). In a prospective study of elite rugby players, Bathgate et al. (2001) found that forwards, especially locks, experienced more injuries than backs (59.4% and 40.8%, respectively). Similarly, in a junior sample (13-21 years old), McIntosh et al. (2010) found that forwards (especially the front row) had the highest rate of injuries to the neck, whereas inside backs had the highest rate of head, neck, and/or face injuries causing the player to miss a game. Divergent findings have also been found in recent systematic reviews, with one study proposing that backs were more likely to sustain a concussion than forwards (4.85 and 4.02 concussions per 1000 match hours, respectively; Gardner et al., 2014); and another concluding that injury susceptibility was found to be similar for forward and back positions (Freitag et al., 2015).

Understanding these differences, or lack thereof, need to be understood in the junior rugby context so as to better direct position-specific preventative training methods. Effective training has been found to moderate the risk of concussion in junior rugby, with players who
train less than 3 hours per week having close to a 50% increased risk of sustaining a concussion (Hollis et al., 2012). Interestingly, Cassidy et al. (2004), Garraway and Macleod (1995), and Hollis et al. (2009) each identified a U-shaped relationship between a rugby experience and the incidence of concussion, with players who had less than 3 years of training and those who had more than 8 years of playing experience reporting higher rates of concussive injury compared to those with between 4 and 8 years of playing experience. This interaction illustrates the need for better understating of the extrinsic moderators to sport-related concussion, as these may change throughout normal adolescent development.

**Safety Behaviours**

Another extrinsic variable that has been widely studied, albeit inconclusively, is the protective benefits of headgear and mouthguards against concussion in rugby, as well as other contact sports. There is minimal consensus in the findings from research evaluating the efficacy of protective gear in minimising concussion incidence in any level of rugby participation. For example, in rugby specific studies both Marshall et al. (2005) and McIntosh et al. (2009) indicated that headgear (i.e., soft shell caps with fixed firm foam padding) had no significant effect on reducing concussion incidence in either junior or senior levels of rugby union competition. In stark contrast, Hollis et al. (2009) and Kemp et al. (2008) found that the use of headgear in amateur and professional rugby decreased athletes’ concussion incidence.

In the face of this contention, two interesting trends have emerged from safety gear studies. Firstly, mouthguards have been made mandatory in junior and senior grades of competition, despite inconclusive evidence on their effectiveness in minimising concussive injury (Harmon et al., 2013; Marshall et al., 2005); while no such legislation has been enforced for headgear. Secondly, it has been noted that protective equipment may lead players to feel more protected and subsequently prompt them to play more aggressively,
thereby increasing their risk of sustaining a concussion (Finch, McIntosh, & McCrory, 2001; Hollis et al., 2009).

This phenomenon, known as risk compensation, proposes that athletes accept a certain level of risk when participating in activities such as contact sport. When the perception of that risk is lowered by interventions such as wearing safety gear, players are likely to actively change their behaviour to regain their desired risk level (e.g., playing rough/more recklessly; Finch et al., 2001; Hagel & Meeuwisse, 2004; Hedlund, 2000; Hollis et al., 2009). This was illustrated in Finch et al. (2001) who studied the attitudes of 140 rugby union players between the ages of 14 and 16 years toward the use of protective headgear, finding that players with no prior head or neck injury were more likely to report that they felt safer wearing protective headgear compared with those with a prior injury. Further, of the players wearing protective headgear, 67% reported that they played with more confidence when they wore the headgear, suggesting that players’ perceptions of improved protection may influence both their behaviour and their attitudes towards injury (Finch et al., 2001). This is concerning considering 62% of high school, university, and community rugby players indicate that they believe headgear could prevent concussion (Pettersen, 2002).

The impact of player attitude on concussion management and return-to-play behaviours is also a concern, considering the suspected high rate of underreporting in junior competition, as discussed in chapter one. Numerous studies have demonstrated associations between team sport participation and health risk behaviours (e.g., drug and alcohol use, delinquency). For example, in an early iconic study, Goldman, Bush, and Klatz (1984) demonstrated that competitive athletes willingly take risks with their health in pursuit of their athletic goals. Although studies investigating this interaction have yielded inconsistent findings since Goldman et al.’s original study, these attitudes about health risks are likely to influence athletes’ attitudes regarding playing style and reporting behaviour (Broshek,
DeMarco, & Freeman, 2015; Finch, Donohue, & Garnham, 2002). Drug and alcohol use may therefore be an extrinsic modifying variable that should be considered in sport-related concussion research, especially as young sportsmen are often implicated in excessive alcohol consumption (Zhou, O’Brien, & Heim, 2014).

Research Aims

The present study aimed to further explore the influence of individual extrinsic factors (i.e., modifiable factors) on sport-related concussion incidence in junior contact sport, as current literature remains largely inconclusive. In a cross-sectional study of junior regional rugby union players, self- and observer- report methods were used to investigate whether; (a), playing position and health-risk behaviours (alcohol consumption and cigarette use, specifically) increased an athlete’s incidence of concussion; and (b), training frequency and use of headgear and mouthguards minimised the incidence of concussion. Differences in the symptomology, management, and return-to-play behaviours of junior rugby players (11-17 years old) were also explored.
Method

Participants

Participants were male junior rugby union players recruited from community clubs throughout the Sunshine Coast region. This cross-sectional cohort study consisted of 259 participants (55% response rate) who were enrolled and actively participating in age-defined teams ranging from under 11- to under 17- year olds. Participants were approached through their local clubs, and data was collected during mid-season training from June to August. Eight of the 11 Sunshine Coast junior rugby union clubs agreed to participate in the present study with 33 teams in the eligible age groups (11-17 year old males; \( M = 13, \, SD = 1.76 \)). On average, athletes had been playing rugby for 4.63 years (\( SD = 2.92 \)).

Measures

**Player information.** Demographic information was collected using both self-report and parental-report questionnaires which included questions regarding the athlete’s age, their playing position, how often they train (both by themselves and with their team), and whether they wear headgear and/or mouthguards while training and during gameplay. Additionally, athletes over 14 years of age were also asked about their smoking and alcohol consumption behaviours.

**Previous concussion.** Details about previous concussions were asked in both the athlete- and parent- report surveys. Participants were asked to identify whether they had ever sustained a concussion, which was defined as “temporary impairment or disruption to brain function caused by any knock to the head, face, neck or body.” Additionally, participants were asked if they had sustained a concussion in the past 12 months; how many times they had been concussed; who diagnosed the injury; the types of symptoms they experienced; how long they were removed from play while they recovered; and if they began wearing headgear once they returned to play. Self-, parent-, and medically trained diagnoses of concussion
were accepted, however only concussive injuries sustained during participation in rugby were included in the final analysis. Inter-rater reliability was assessed for self- and parental report data. No significantly divergent responses occurred in this sample, with most responses being strongly correlated between athletes and their parents ($r = .92, p < .01$).

**Health and fitness.** Height and weight measures were taken for each athlete to calculate their body mass index (BMI; weight in kilograms divided by squared metres of height; NHMRC, 2013). Height measurements were taken using a standard stadiometer while the participants were barefoot and facing directly forward (i.e., away from the slide ruler on the stadiometer). A digital weight scale was used to weigh each participant, who remained barefooted and in normal training clothes. Height and weight measures were both recorded to two decimal points. Participant’s aerobic fitness was assessed using a multi-stage 20 metre shuttle run (i.e., Beep Test), which is widely used and valid measure of VO$_2$ max (Leger et al., 1988). The 20 metre shuttle run test is a reliable measure for use in both child ($r = 0.89$) and adult ($r = 0.95$) populations, with significant test-retest reliability ($p = <.05$; Leger et al., 1988). Participants are instructed run between two markers set 20 metres apart, keeping pace with a pre-recorded tone. The pace increases by 0.5km/h$^{-1}$ each minute as the test progresses through the 21 stages, which consist of eight to 15 laps within each stage. The test concludes when the individual is no longer able to reach the line before the tone, awarding the last announced stage as the participant’s score. This test was run on the football field surface and participants were instructed to wear their normal football boots to facilitate consistency between all participants in the study. Each of these measures were taken during each teams’ regular scheduled football training after the athletes had warmed up. Each participants’ scores were compared against national averages (NHMRC, 2013; Olds et al., 2006).
Procedure

Ethical approval for this study was granted by the Sunshine Coast University Human Research Ethics Committee (S/14/662). Support was sought from the district rugby coordinators (Sunshine Coast Stingrays) before the coaches of individual teams were contacted. Participants were approached by the research team during their weekly training sessions at their home field, where the aim of the study and participation details were explained. Athletes who wished to participate in the study were given an information pack to take home; this included a consent form and information sheet as well as the demographic and psychometric questionnaires for both themselves and their parents/guardians to complete (see appendices 1 to 4). The following week, athletes who had returned their consent forms (either by mail or directly to the research team) had their biometrics measured. Following a brief warm up (conducted by the team coach), athletes completed the beep test as a team (up to 15 players simultaneously) at the beginning of their regularly scheduled training session. Questionnaires completed by both the athlete and their parent/guardian were returned to the research team either directly or via Australia Post in the reply paid envelopes that were provided. Questionnaires that were at least 80% complete were included in analysis; respondents who did not return both the athlete and parent report questionnaires were excluded from the study (n = 2). Once both physical and written data had been collected and matched to the participant, data were de-identified prior to analysis to protect the privacy of the participants.

Results

Player Characteristics

Of the 259 male junior rugby players (mean age 13 years, SD = 1.8), 52.9% of the sample identified as playing primarily in a forward position (i.e., Hooker, Prop, Lock, Flanker, or Eight) compared to 43.2% who played in a back position (i.e., Halfback, Five-
Eight, Centre, Wing, or Fullback). The remaining players (3.5%) identified as having more than one position. The mean height of the sample was 160.9 centimetres ($SD = 13.4$); and weight was 55.1 kilograms ($SD = 16.5$); giving a mean body mass index of 20.8 ($SD = 3.7$) for the sample, which is within the ‘average’ range ($BMI = 14.6 – 22$) as defined by the NHMRC (2013). The average beep test score for the sample was 8.2 ($SD = 2.1$), which is considered ‘average’ by national standards (Olds et al., 2006).

The inter-correlation matrix of the independent variables are displayed in Table 8. Illustrative of the typical physical characteristics associated with forward and back positions, playing in a front position was significantly positively correlated with players’ BMI ($r = .39$, $p = <0.1$), and negatively correlated with ‘beep’ score ($r = -.27$, $p = <0.1$). Conversely, playing in a back position was significantly negatively correlated with BMI ($r = -.40$, $p = <0.1$), and positively correlated with ‘beep’ score ($r = .30$, $p = <0.1$).

On average, players spent more time training with their team than by themselves ($M = 2.9hrs/week$, $SD = .58$ and $M = 1.8hrs/week$, $SD = 1.1$, respectively). Over 80% of players trained for more than 3 hours per week with their team, compared to only 24% who trained independently for 3 or more hours per week. In the older age group (14-17 years; $n = 106$, $M = 14.9yrs$, $SD = .90$), majority (82.1%) of participants reported that they ‘never’ consumed alcohol. Two-thirds (66%) of respondents who did consume alcohol ($n = 18$) reported drinking 1 to 4 drinks in one session and 10% reported drinking more than 10 drinks in one session. None of the participants smoked cigarettes.

During training, 55% of players reported ‘always’ wearing a mouthguard (6.6% ‘never’ wore one); during a game almost all players wore a mouthguard (96.9%). Over half (55%) of the players ‘rarely’ or ‘never’ wore headgear during training, whereas 61% ‘often’ or ‘always’ wore it during gameplay. There was a significant negative correlation between athlete’s age and use of headgear and mouthguards during training ($r = -.21$, $p = <0.1$ and $r =$
-.40, \( p = <0.1 \), respectively). The same trend was seen for use of protective wear during gameplay, however this was non-significant. Following experiencing a rugby-related concussion 37\% of players began wearing headgear, however 18\% indicated they were wearing it when they were injured.
### Table 8. Inter-correlations of individual behavioural factors and rugby-related concussion

<table>
<thead>
<tr>
<th></th>
<th>M</th>
<th>SD</th>
<th>Age</th>
<th>BMI</th>
<th>Training Team</th>
<th>Training Self</th>
<th>Headgear Training</th>
<th>Headgear Game</th>
<th>M’guard Training</th>
<th>M’guard Game</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concussion history</td>
<td>†</td>
<td>†</td>
<td>.33**</td>
<td>.15*</td>
<td>.17**</td>
<td>.11</td>
<td>.06</td>
<td>.05</td>
<td>.09</td>
<td>.01</td>
</tr>
<tr>
<td>Age</td>
<td>13.0</td>
<td>1.7</td>
<td>-</td>
<td>.463**</td>
<td>.205**</td>
<td>-.076</td>
<td>.232**</td>
<td>.106</td>
<td>.396**</td>
<td>.099</td>
</tr>
<tr>
<td>BMI</td>
<td>20.8</td>
<td>3.7</td>
<td>.463**</td>
<td>-</td>
<td>.083</td>
<td>-.008</td>
<td>.049</td>
<td>.033</td>
<td>.236**</td>
<td>.139*</td>
</tr>
<tr>
<td>Training – Team (hrs)</td>
<td>2.9</td>
<td>.6</td>
<td>.205**</td>
<td>.083</td>
<td>-</td>
<td>.125*</td>
<td>.017</td>
<td>-.026</td>
<td>.019</td>
<td>.040</td>
</tr>
<tr>
<td>Training – Self (hrs)</td>
<td>1.8</td>
<td>1.1</td>
<td>-.076</td>
<td>-.008</td>
<td>.125*</td>
<td>-</td>
<td>-.072</td>
<td>-.059</td>
<td>.003</td>
<td>.100</td>
</tr>
<tr>
<td>Headgear - Training</td>
<td>3.4</td>
<td>1.6</td>
<td>.232**</td>
<td>.049</td>
<td>.017</td>
<td>-.072</td>
<td>-</td>
<td>.710**</td>
<td>.347**</td>
<td>.126*</td>
</tr>
<tr>
<td>Headgear - Game</td>
<td>2.4</td>
<td>1.8</td>
<td>.106</td>
<td>.033</td>
<td>-.026</td>
<td>-.059</td>
<td>.710**</td>
<td>-</td>
<td>.162**</td>
<td>.207**</td>
</tr>
<tr>
<td>Mouthguard - Training</td>
<td>1.9</td>
<td>1.3</td>
<td>.396**</td>
<td>.236**</td>
<td>.019</td>
<td>.003</td>
<td>.347**</td>
<td>.162**</td>
<td>-</td>
<td>.284**</td>
</tr>
<tr>
<td>Mouthguard - Game</td>
<td>1.1</td>
<td>.4</td>
<td>.099</td>
<td>.139*</td>
<td>.040</td>
<td>.100</td>
<td>.126*</td>
<td>.207**</td>
<td>.284**</td>
<td>-</td>
</tr>
</tbody>
</table>

† Means and SD not available for binary variables. * Correlations are significant at the .05 level (2-tailed); ** Correlations are significant at the .01 level (2-tailed).
Concussion History

Sixty-six participants (25.6%) indicated they had sustained a concussion at some stage while participating in rugby union. Athlete and parent reports of concussion were strongly correlated ($r = .92, p < .01$). Team medics, family doctor/general practitioners, and hospital/emergency room doctors were named most frequently as being responsible for diagnosing concussion (57.4%, 14.9%, and 10.6%, respectively). Over half of the sample (58.5%; $n = 38$) reported having experienced only a single sport-related concussion; 23.1% ($n = 15$) reported having a history of two concussions; 13.8% ($n = 9$) reported a history of 3-4 concussions; and the remaining 4.6% ($n = 3$) reported having sustained five or more rugby-related concussions.

Players reported experiencing an average of 5.4 concussion symptoms ($SD = 2.8$). Headache, dizziness, and blurred vision were reported in the majority of cases (respectively, 93%, 80%, and 57% of the time). Athletes who played in back positions more frequently reported symptoms such as disorientation, loss of memory, and loss of consciousness; compared to forwards who more frequently reported symptoms of nausea, light and sound sensitivity, and drowsiness/fatigue (see Table 9). There was no significant difference between playing position (forwards, backs, or multiple positions) and incidence of concussion ($F (2) = .15, p = .86, \eta^2 = .01$), frequency of concussion ($F (2) = .63, p = .54, \eta^2 = .30$), or total number of concussive symptoms experienced ($F (2) = .26, p = .77, \eta^2 = .68$). Two-thirds (66%) of respondents stated their concussive symptoms receded with 24 hours; 16% within 1-3 days; and 10% took longer than a week to recover. Most athletes (59%) stopped playing and training while they recovered. Return-to-play varied between ‘same day’ (40.3%), ‘within 7 days’ (35.8%), and ‘within 2-3 weeks’ (19.4%). Three players indicated that they did not return to play after being injured.
**Predictive analyses.** To assess the influence of an athlete’s playing position, health-promoting and health-risk behaviours (i.e., wearing safety gear; substance use), and training frequency on the incidence of reporting a rugby-related concussion, a logistic regression was performed. The binary dependent variable was concussion history (i.e., 1 = participant has sustained a rugby-related concussion; 0 = no concussion history).

<table>
<thead>
<tr>
<th>Symptom</th>
<th>Frequency*</th>
<th>Total %**</th>
<th>Forward ^</th>
<th>Backs^</th>
</tr>
</thead>
<tbody>
<tr>
<td>Headache</td>
<td>64</td>
<td>92.8</td>
<td>47</td>
<td>48</td>
</tr>
<tr>
<td>Dizziness</td>
<td>55</td>
<td>79.7</td>
<td>49</td>
<td>47</td>
</tr>
<tr>
<td>Blurred vision</td>
<td>39</td>
<td>56.5</td>
<td>46</td>
<td>49</td>
</tr>
<tr>
<td>Loss of balance</td>
<td>34</td>
<td>49.3</td>
<td>47</td>
<td>47</td>
</tr>
<tr>
<td>Nausea</td>
<td>30</td>
<td>43.5</td>
<td>53</td>
<td>43</td>
</tr>
<tr>
<td>Disorientation</td>
<td>29</td>
<td>42</td>
<td>41</td>
<td>59</td>
</tr>
<tr>
<td>Drowsiness/fatigue</td>
<td>23</td>
<td>33.3</td>
<td>52</td>
<td>43</td>
</tr>
<tr>
<td>Poor concentration</td>
<td>20</td>
<td>29</td>
<td>45</td>
<td>50</td>
</tr>
<tr>
<td>Loss of memory</td>
<td>20</td>
<td>29</td>
<td>20</td>
<td>75</td>
</tr>
<tr>
<td>LOC</td>
<td>16</td>
<td>23.2</td>
<td>38</td>
<td>63</td>
</tr>
<tr>
<td>Sensitivity to light</td>
<td>11</td>
<td>15.9</td>
<td>55</td>
<td>45</td>
</tr>
<tr>
<td>Vomiting</td>
<td>8</td>
<td>11.6</td>
<td>25</td>
<td>75</td>
</tr>
<tr>
<td>Numbness/tingling</td>
<td>7</td>
<td>8.7</td>
<td>86</td>
<td>14</td>
</tr>
<tr>
<td>Nervousness</td>
<td>5</td>
<td>7.2</td>
<td>60</td>
<td>40</td>
</tr>
<tr>
<td>Aggressiveness</td>
<td>4</td>
<td>5.8</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>Sensitivity to sound</td>
<td>3</td>
<td>4.3</td>
<td>67</td>
<td>33</td>
</tr>
<tr>
<td>Depression/irritability</td>
<td>2</td>
<td>2.9</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>Sleep disturbance</td>
<td>2</td>
<td>2.9</td>
<td>0</td>
<td>100</td>
</tr>
</tbody>
</table>

\[ M (SD) \quad \hat{5}.4 (2.8) \quad \hat{5}.2 (2.5) \quad \hat{5}.7 (3.0) \]

*Note. * Number of times each symptom was reported. ** Percentage of the total sample who experienced this symptom. ^ Percentage of forward or back players (n = 33 each) who
Extrinsic behavioural variables were found to explain 17.7% of variance in concussion incidence (Nagelkerke $R^2 = .177$), correctly predicting 78% of rugby-related concussion incidence. Hosmer and Lemeshow was non-significant indicating goodness of fit and hence no significant discrepancy between observed and predicted concussion incidence ($\chi^2 (8) = 6.05, p = .64$). This regression model together was non-significant ($\chi^2 (25) = 32.58, p = .14$), however specific behavioural variables which did contribute significantly to the model were ‘never wearing a mouthguard during training’ ($ExpB [.99, 11.44] = 3.36, SE = .63, p = 0.5$); ‘never wearing headgear while training’ ($ExpB [1.0, 12.08] = 3.47, SE = .64, p = 0.5$); and ‘training for 5 or more hours independently’ ($ExpB [1.28 – 21.09] = 5.2, SE = .71, p = .02$).

**Discussion**

There were significant size and aerobic fitness differences between forward and back playing positions, demonstrating the commonly held notion that forwards are bigger compared to backs, who are smaller and faster. Athletes who played in a back position reported more symptoms of concussion, however there was no significant difference between playing position and incidence of concussion or total number of concussive symptoms experienced in this sample. This is consistent with previous research (Freitag et al., 2015; Gardner et al., 2014). Contradictions to these findings may be due to rule modifications implemented in junior rugby (e.g., no lifting, illegal sling tackles; ARU, 2014) which seek to minimise the possible head and neck injuries associated with tackles and scrums, which have been found to account for high rates of concussive injury (Freitag et al., 2015).
The extrinsic variables that impacted the incidence of reporting a concussion most were training related behaviours, specifically time spent training unsupervised and use of protective gear when training. Although players spent more time training with their team than independently, athletes who trained unsupervised for 5 or more hours per week, either alone or with a friend, were over five times more likely to report a rugby-related concussion ($ExpB = 5.2$). Based on an early study by Silva and Gill (1988) who looked at spinal injuries in junior rugby, it can be proposed that this increased incidence may be due to irresponsible behaviours or game rules being overlooked when players are unsupervised. Adolescent egocentrism creates a false sense of uniqueness and invulnerability (Greene et al., 2000), which may lead to heightened incidence of subsequent injury. Compounding with the effect of reduced awareness of subject-object interaction (i.e., egocentricity), the pseudo-cultural masculine pressure for rugby players to ‘play tough’ (Kerr et al., 2014; Wiese-Bjornstal, 2010) may encourage young athletes to play more recklessly when training unsupervised – especially when training with their friends.

In conjunction with this finding, during training over half of the players in the present study ‘rarely’ or ‘never’ wore headgear, in addition to a small portion who ‘never’ wore a mouthguard. Furthermore, athletes who never wore headgear or a mouthguard during training were found to be up to 3.4 times more likely to have a history of rugby-related concussion, with player age being negatively correlated with use of headgear and mouthguards. At face value this finding may appear to provide support for the efficacy of mouthguards and headgear in reducing the incidence of concussion, however as there was no significant inverse interaction observed between players who ‘always’ wore protective gear during training and concussion incidence, alternative hypotheses need to be explored. Despite having more developed risk-assessment ability compared to younger athletes, health-protecting behaviours (e.g., use of protective
equipment) have been shown to decline during adolescence, especially in regards to use of protective wear to prevent sports injuries (Finch, Donohue, & Garnham, 2002; McIntosh et al., 2009). Therefore the findings from this study may provide less support for the efficacy of protective wear, and instead illustrate the need to look at individual player characteristics and/or playing styles (e.g., adolescent athlete with an egocentric playing style). The positive interaction between unsupervised training and concussion incidence also needs to be explored further, as sports such as rugby are demanding, tactical, and require a high level of skill – which requires effective training methods and strategies.

A positive finding from this study was the absent use of cigarettes and low reported use of alcohol in the 14-17 year old players. Under 10% of participants in this study consumed alcohol on a monthly or weekly basis, which is considerably lower than the national average of 86.2% for this age group (AIHW, 2014). Contrary to the controversial relationship often presented between sport participation and alcohol use, this finding suggests participation in a team sport may have a health-promoting function for adolescents, which compliments previous research (e.g., McHale et al., 2005). Future research into regional adolescent team sport should aim to investigate this further using control measures, as the present study’s finding is limited by the absence of a control group.

**Conclusion**

Concussive injury may never be completely eliminated from rugby and other contact sports, however better understanding the actions and activities (i.e., extrinsic factors) that typically result in concussions may modulate the incidence of concussion in junior sport. The present study aimed to address the inconsistencies in literature by exploring the influence of modifiable extrinsic factors on the incidence of rugby-related concussion. The main findings
from this study were, (a) playing position had no significant impact on concussion incidence; and (b) training frequency and behaviour did significantly predict concussion incidence; specifically time spent training unsupervised and use of protective gear when training. To minimise incidence of sport-related concussion in junior rugby, future interventions may seek to revise training structures and improve players’ awareness of the importance of good technique. Movements towards promoting the internalisation of the severity of concussive injury so as to improve young athletes’ awareness of subject-object interaction (i.e., dissipate the false sense of invulnerability) would also be beneficial.

**Limitations.** One of the noteworthy limitations of the present study was the lack of detail regarding athletes’ training behaviours. As training frequency was found to be a predictive variable of rugby-related concussion, it would be advantageous for future research to explore specific training behaviours adolescents engage in, and whether these differ between supervised and unsupervised practice. A more specific study exploring the interaction between training behaviours and concussion incidence would also be advantageous to prevent the chance of Type I errors occurring. As with Study 1, the retrospective nature of the concussion data collected prevented injury risk from being calculated. It also may have incurred some recall bias due to time lapse between injury and participation in this study. Although this was somewhat addressed by administering both parent- and self-report questionnaires, future studies would benefit from employing a prospective study design. This study focused on the impact of extrinsic behavioural variables on the incidence of reporting a rugby-related concussion; as such, the future research may benefit from a larger sample size to prevent Type II errors from occurring.
Study Three - Cognitive and Emotional Consequences of Adolescent Concussion: A Between-Groups Cross-Sectional Analysis

Concussion is characterised by a rapid onset of cognitive disruption to functions such as memory, concentration, and orientation; typically resolving within seven to 10 days (McCrory et al., 2013). Several prospective studies have consistently demonstrated that the majority of athletes who sustain a concussion achieve a complete recovery within one to two weeks (Belanger & Vanderploeg, 2005; Broglio & Puetz, 2008), however the recovery time for younger athletes has been suggested to take longer than collegiate and adult populations (Field, Collins, Lovell, & Maroon, 2003; Grady, 2010). Furthermore, cognitive performance deficits have been observed in high school aged athletes for up to 10 to 14 days (Lau, Collins, & Lovell, 2012; McClincy et al., 2006); compared to collegiate athletes who took an average of five to seven days (McCrea et al., 2003); and adult athletes who only took three to five days (Field et al., 2003; McCrea et al., 2003). Despite the growing attention in research on the recovery profile for paediatric and adolescent concussion, it remains unclear why some athletes suffer adverse and ongoing complications, while others return to play with no post-concussive symptoms or other functional impairments.

Recovery Profile in Adolescence

Current literature on the recovery profile of adolescents following concussion is limited and has produced largely mixed results. Following a meta-analysis of the neuropsychological impact of sport-related concussion, acute immediate effects were strongest for delayed memory, memory acquisition, and global cognitive functioning (Belanger & Vanderploeg, 2005). However in a clinical study on the duration and course of post-concussive symptoms in 11 to 22 year old patients, Eisenberg, Meehan, and Mannix (2014) found that the majority of adolescents
initially presented with symptoms of headaches and dizziness, with only minor complaints of cognitive disruption (i.e., ‘taking longer to think’), all of which abated within 7 to 10 days. Furthermore, additional emotional symptoms were found to develop during the course of recovery, particularly sleep disturbance, irritability, forgetfulness, and poor concentration (which persisted for 14 to 16 days; Eisenberg, Meehan, & Mannix, 2014). The mechanisms underlying the development of secondary symptoms are unknown; while it could be attributed to the underlying pathophysiology of concussive injury, it may also be a reaction to recovery restrictions from physical and cognitive exertion (Eisenberg et al., 2014).

Some studies have suggested that the neuroanatomical changes occurring throughout adolescence (e.g., proliferation of synapses, increased myelination) may expedite neuroplasticity, facilitating cognitive recovery following concussion (Graham, Rivara, Ford, & Spicer, 2014). Conversely, the relative immaturity of the brain during adolescence (compared to collegiate and adult samples) has been presented as a possible risk factor for longer recovery times and long-term neurodevelopmental disruptions following head injury (Karlin, 2011; Kirkwood, Yeates, & Wilson, 2006; Patel & Reddy, 2010). It has been proposed that the translational force of impact may place more neurological strain on younger athletes due to the incomplete myelination and elasticity of the developing brain (Karlin, 2011; Ommaya, Goldsmith, & Thibault, 2002). Due to this potential ‘second sensitive period’ (as discussed in chapter two), cognitive disruption resulting from concussion may alter the natural timeline of neuronal maturation during adolescence (Blakemore & Choudhury, 2006; Fields, 2005; Luna et al., 2004). Therefore, with consideration for the rapid neurological and physical development in adolescence, it has been widely recommended that junior athletes be given a cognitive assessment every six months to allow accurate comparison in the event of a concussion (Borich et al., 2013; Valovich-McLeod et
al., 2012). This is often beyond the resources of some junior and community sporting clubs, leaving young athletes at risk of both under diagnosis and misdiagnosis.

**Ongoing Complications**

There is minimal consensus regarding the effect of sustaining a concussion during childhood or adolescence on development and later functioning (Belanger & Vanderploeg, 2005; Halstead & Walter, 2010). In one longitudinal study on the effects of concussion on children (3 to 12 years of age), Anderson et al. (2005) found that although participants had significantly reduced performance on cognitive tasks at 6 and 30 months after injury (compared to age-matched controls), they eventually improved over time. This suggests that the transient impairments associated with concussion in children may cause a delay in the acquisition of neurodevelopmental skills rather than any permanent deficits (Anderson et al., 2005).

Conversely, there have been some significant developmentally pertinent delays identified in this age group following mild traumatic brain injury, including interruptions to school work and/or home activity (Fay et al., 2010); executive functioning and attention (Catale et al., 2009); and verbal intelligence an expressive language (Daneshvar et al., 2011). Following a longitudinal study of the trajectories of post-concussive symptoms in children and adolescents (8 to 15 years old), it was emphasised that the experience of long-term neurobehavioural concussive symptoms is related to individual baseline neuropsychological functioning, academic performance, emotional adjustment, and adaptive functioning (Yeates et al., 2009). The absence of consideration for individual intrinsic factors in assessing the recovery profile of children and adolescents following a concussive injury has limited the current research literature.

Although it is essential to better understand the recovery profile of children and adolescents following a concussion, the stages of typical cognitive and psychosocial
development should also be considered. For example, attention span, cause-and-effect, and planned behaviour are still developing during pre-adolescence (~11 years old), all of which may be confused with- or impact upon enduring concussion symptomology (Karlin, 2011). Similarly, the increased narcissism, rebellion, and concern with social appearance typically exhibited during early and middle adolescence (12 to 16 years) may influence underreporting and treatment compliance, both prolonging injury and placing the individual at greater risk of repeat concussion (Karlin, 2011). When this typical developmental progression is considered in the assessment of concussive symptoms and subsequent recovery, the importance of informing adolescent recovery profiles on regular baseline neuropsychological testing is clearly highlighted to ensure concussion is being properly identified and managed.

Failure to diagnose concussion is a concern for two reasons. First, research has shown that concussed players who are not removed from play are at higher risk for additional concussions (McCrea et al., 2004; Talavage et al., 2014). Second, following on from neurophysiological research which suggests that concussion may have a dosage effect (Anderson et al., 2005; Guskiewicz et al., 2004; McKee et al., 2009; Ommaya, Goldsmith, & Thibault, 2002); athletes who are not removed from play could accumulate sub-concussive injury resulting from multiple minor impacts. While this effect has been observed in several post-mortem studies which have identified neural scarring and degeneration in excess of the clinical concussion histories of the deceased athlete (Guskiewicz et al., 2004; McKee et al., 2009), research on the interaction between repeated concussion during childhood and later cognitive and motor function is contentious. The current literature on the long-term consequences of concussion is notably limited by a sparseness of research on paediatric and adolescent populations, as well as the reliance on self-reported injuries.
Research Aims

To address the limitations that presently exist in literature, this study aimed to investigate the impact of medically diagnosed concussion on cognitive and emotional functioning in an adolescent population using readily accessible measures, such as school grades and parent-reported executive functioning. Through the use of a multi-measure cross sectional research design, possible changes in cognitive and emotional functioning were explored in individuals across adolescent development (11 to 17 years) who have sustained both single and multiple concussions. It is hypothesised that following a single concussive injury, any decline in academic performance, emotion, and/or executive function in early adolescence will be only be temporary (i.e., recovered within 7 to 10 days), and will not be significantly identifiable in older adolescence. Additionally, following on from the assertion that concussion may have a dosage effect on cognitive and emotional function, it is also hypothesised that greater deficits will be observed in adolescents who have sustained multiple concussive injuries, compared to those who have sustained only a single concussion.
Method

Participants

Participants were male junior rugby union players recruited from community clubs throughout the Sunshine Coast region. Participants were approached through their local clubs, and data was collected during mid-season training from June to August. Eight of the 11 Sunshine Coast junior rugby union clubs agreed to participate in the present study with 33 teams in the eligible age groups (11-17 year old males). This cross-sectional cohort study consisted of 259 participants (55% response rate) who were enrolled and actively participating in age-defined teams ranging from under 11- to under 17- year old ($M = 13$, $SD = 1.8$). On average, athletes had been playing rugby for 4.6 years ($SD = 2.9$).

Measures

Demographic information was collected using both self-report and parental-report questionnaires which also included questions regarding the athletes’ average school grades and details of their concussion history.

Executive function. Executive function was measured using the parent report version of the Behaviour Rating Inventory of Executive Function (BRIEF-PR; Gioia, Isquith, Guy, & Kenworthy, 2000). This is an 86-item paper-and-pencil questionnaire which evaluates the emotional, behavioural, and metacognitive skills (broadly described as executive abilities). This questionnaire uses a three-point scale, with possible responses including ‘Never’, ‘Sometimes’, and ‘Often’. The BRIEF-PR is an ecologically valid measure of the manifestations of EF in daily life, such as impact on school, family functioning, and social relationships, and is widely used in EF assessments of child and adolescent development (Gioia et al., 2000). The BRIEF-PR has been used to evaluate the executive functions of children and adolescents presenting with
a wide range of concerns, both non-clinically and clinically (e.g., in child and adolescent populations diagnosed with attention deficit/hyperactivity disorder, autism spectrum disorder, and traumatic brain injury (Gioia et al., 2000).

An overall index of executive dysfunction is provided by the Global Executive Composite (GEC), which is comprised of two subordinate indices called the Behavioural Regulation Index (BRI) and the Metacognition Index (MCI). The BRI is comprised of three subscales, including ‘Inhibit’ (e.g., delay or stop impulsive behaviours), ‘Shift’ (e.g., change tasks and adapt to new situations) and ‘Emotional Control’ (e.g., modulate mood appropriately). The MCI is comprised of five subscales, including ‘Initiate’ (e.g., generate ideas, start new tasks), ‘Working Memory’ (e.g., sustain one’s focus, keep information in mind), ‘Plan/Organise’ (e.g., think prospectively, follow a plan), ‘Organisation of Materials’ (e.g., clean-up after oneself), and ‘Monitor’ (e.g., check one’s work for errors, monitor the effect of one’s behaviour on other people). Item scores are computed as \(T\) scores, which are then compared against normative data, which also provides percentile ranking and 90% confidence interval values for each scale by gender and for four age groupings (i.e., 5 to 7 year olds, 8 to 10 year olds, and 14 to 18 year olds). The BRIEF-PR has a Cronbach's \(\alpha\) coefficient measure of internal consistency ranging from .80 to .98 for clinical and normative samples, respectively (Gioia et al., 2000). The reliability alpha for this sample was strong (\(\alpha = .95\)). This measure has a high test-retest reliability correlation across each of the scales (mean \(r = .81\)) after an average interval of two weeks. In the non-clinical sample, BRI, MCI, and GEC retest correlations were .84, .88, and .86 respectively (Gioia et al., 2000).

**Concussion history.** Concussion was presented to participants as being “temporary impairment or disruption to brain function caused by any knock to the head, face, neck or body”.

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*Note:* The text above has been reformatted for readability and coherence, maintaining the original meaning and context.
Participants were then asked to identify whether they had ever sustained a concussion while partaking in *any* activity, how many times they had been concussed, who diagnosed the injury, and how long they were removed from play while they recovered. Only those concussion that were diagnosed by medically trained personnel (e.g., team medic, emergency service respondent, doctor) were considered in this study.

**Emotional functioning.** The Revised Children’s Anxiety and Depression Scale (RCADS; Chorpita et al., 2000) was used to evaluate participants’ emotional functioning. This 47-item measure is an adaptation of the Spence Children’s Anxiety Scale (SCAS; Spence, 1997) intended to assess children's report of symptoms corresponding to selected *DSM-IV* anxiety disorders and depression. The adapted measure includes subscales for separation anxiety, social phobia, generalized anxiety, panic disorder, obsessive compulsive disorder, and major depressive disorder. Test-retest reliability has been found to be favourable for each of the RCADS subscales, in addition to strong structural, convergent, and discriminant validity in 8 to 18 year old populations (Chorpita et al., 2000). Cronbach’s alpha for this study was strong (*α* = .95).

**Procedure**

Ethical approval for this study was granted by the Sunshine Coast University Human Research Ethics Committee (S/14/662). Support was sought from the district rugby coordinators (Sunshine Coast Stingrays) before the coaches of individual teams were contacted. Participants were approached by the research team during their weekly training sessions at their home field, where the aim of the study and participation details were explained. Athletes who wished to participate in the study were given an information pack containing a consent form, information sheet, self-report and parent-report demographic questionnaires (which included the RCADS questionnaire; see appendices 1 to 4) as well as the BRIEF-PR. Questionnaires completed by
both the athlete and their parent/guardian were returned to the research team either directly or via
Australia Post in the reply paid envelopes that were provided. Questionnaires that were at least
80% complete were included in analysis; respondents who did not return both the athlete and
parent report questionnaires were excluded from the study ($n = 2$). Data were coded and
recorded in a de-identified SPSS data file to protect the privacy of the participants.

Results

Descriptive statistics

IBM SPSS Statistics for Windows, version 22.0, was used to calculate the following
analyses. Of the 259 participants in the study (mean age 13 years old; $SD = 1.8$), 29% ($n = 75$)
reported having sustained a concussion at some stage in their lives, as diagnosed by medically
trained personnel. Team medics (55.6%), family doctors/general practitioners (27.7%), and
hospital/emergency room (16.7%) were most frequently identified as the source of the
concussion diagnosis. Forty-one percent of the sample reported experiencing more than one
concussion; including 36% who reported experiencing two to three concussions, and 5% who
had experienced four or more. The majority of participants (70%) sought medical attention for
their injury, namely their family doctor/general practitioner (33%), the hospital/emergency room
(17.8%), or their team’s medic (16.7%).

Sixty-one percent of participants believed they had recovered from their injury within 24
hours; 21% within one to three days; 11% within four to 10 days; and 6.7% took longer than two
weeks. After sustaining a concussion, nearly 40% of participants did not stop training/playing
rugby union or returned to play on the same day of their injury; 31.5% returned within seven
days; 12% took one to two weeks; and 11% returned to play within two to three weeks. Four
participants (5.5%) did not return to play after sustaining a concussion. Independent $t$ test was
used to assess age-related differences in average recovery time between younger (11-13 years old; \( n = 33 \)) and older adolescents (14-17 years old; \( n = 42 \)). Equal variance was assumed as Levine’s test for equality of variance was non-significant (\( p > .05 \)). The \( t \) test was non-significant (\( t (73) = -.68, p = .50, 95\% \text{ CI} = -.85 \text{ -- } -.42, \text{ Cohen’s} \text{ } d = .08 \)), indicating that the average recovery time for younger and older adolescents was not significantly different.

Table 10 shows the participants’ mean scores for the RCADS, BRIEF-PR, and their average school grades. RCADS and BRIEF-PR scores were converted to T-scores for cross-sectional comparison, and were all within the ‘normal’ range. Self-reported data regarding average school grades was compared against parent report data to avoid response bias; means were not significantly different between the two groups (\( p < .01 \)).

Table 10. Participant scores: RCADS and BRIEF-PR means and average school grade distribution

<table>
<thead>
<tr>
<th></th>
<th>( N )</th>
<th>( M )</th>
<th>( SD )</th>
</tr>
</thead>
<tbody>
<tr>
<td>RcADS</td>
<td>254</td>
<td>44.22</td>
<td>10.57</td>
</tr>
<tr>
<td>Total anxiety score</td>
<td>42.49</td>
<td>10.34</td>
<td></td>
</tr>
<tr>
<td>BRIEF-PR</td>
<td>239</td>
<td>50.3</td>
<td>10.14</td>
</tr>
<tr>
<td>Behaviour Regulation Index</td>
<td>52.26</td>
<td>10.42</td>
<td></td>
</tr>
<tr>
<td>Meta-Cognition Index</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Global Executive Function</td>
<td>51.67</td>
<td>10.61</td>
<td></td>
</tr>
<tr>
<td>Average school grades</td>
<td>257</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mostly A</td>
<td>52 (20.2%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mostly B</td>
<td>135 (52.5%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mostly C</td>
<td>66 (25.7%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mostly D</td>
<td>4 (1.6%)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Note. Means not available for categorical variables.*

**Concussed versus Non-Concussed**
An independent $t$ test was used to compare the average T-scores for the RCADS and BRIEF-PR of participants in the ‘concussed’ condition (C1; $n = 75$) against the average T-scores of the participants in the ‘non-concussed’ condition (C2; $n = 184$). Equal variance can be assumed as Levine’s test for equality of variance was non-significant for the ‘Anxiety’ and ‘Depression’ subscales of the RCADS, and non-significant for the ‘Behaviour Rating Inventory’ and ‘Meta-Cognitive Index’ subscales of the BRIEF-PR. Equal variance was not assumed for the ‘Global Executive Function’ scale of the BRIEF-PR as Levine’s statistic was violated ($F = 8.02, p = .005$). The $t$ test was non-significant, with the ‘concussed’ group (C1) reporting similar scores to the ‘non-concussed’ group (C2) for ‘Anxiety’ (C1 $M = 41.89, SD = 9.13$; C2 $M = 42.71, SD = 10.84$); ‘Depression’ (C1 $M = 43.27, SD = 10.47$; C2 $M = 44.64, SD = 10.63$); ‘Behaviour Rating Inventory’ (C1 $M = 48.69, SD = 9.35$; C2 $M = 50.87, SD = 10.41$); ‘Meta-Cognitive Index’ (C1 $M = 51.55, SD = 9.65$; C2 $M = 52.49, SD = 10.72$); and ‘Global Executive Function’ (C1 $M = 49.9, SD = 8.71$; C2 $M = 52.31, SD = 11.22$). The effect size (Cohen’s $d$) for all subscales was -.01, indicating a small negative effect. See Table 11 for $t$ test statistics for these subscales.

A $t$ test was also used to explore differences in average school grades between participants in C1 ($M = 2.01, SD = .65$) and participants in C2 ($M = 2.12, SD = .75$). Levine’s statistic was violated ($F = 7.83, p = .006$), thus equal variance was not assumed. The $t$ test showed no significant difference between the school grades of the two groups ($t (156.61) = -.89, p = .38, 95\% CI = -.27 – .10, d = -.06$).

**Single versus Multiple Concussion**

An independent sample $t$ test was used to compare the average T-scores for the RCADS and BRIEF-PR of participants who reported sustaining a single concussion (C3; $n = 44$) against
the average T-scores of the participants who reported sustaining more than one concussion in their lives (C4; \( n = 31 \)). Equal variance was assumed as Levine’s test for equality of variance was non-significant for all subscales (\( p > .05 \)). The \( t \) test was non-significant for all subscales, with C3 reporting similar scores to C4 on all measures (\( d = -.03 \); see Table 10 for \( t \) test statistics). A \( t \) test was also used to explore differences in average school grades between participants in C3 (\( M = 2.14, SD = .67 \)) and participants in C4 (\( M = 1.87, SD = .57 \)). The \( t \) test showed no significant difference between the school grades of the two groups (\( t (72) = 1.81, p = .08, 95\% CI = -.03 – .57, d = .22 \)).

Table 11. Mean differences in executive and emotional functioning between concussion groups

<table>
<thead>
<tr>
<th></th>
<th>( t )</th>
<th>df</th>
<th>( p^* )</th>
<th>Mean diff.</th>
<th>95% CI</th>
<th>( d^{**} )</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>C1</strong> ( (n = 75) ) v <strong>C2</strong> ( (n = 184) )</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total anxiety score</td>
<td>-.55</td>
<td>252</td>
<td>.58</td>
<td>-.79</td>
<td>-3.64 – 2.04</td>
<td>-.04</td>
</tr>
<tr>
<td>Major depressive disorder</td>
<td>-.85</td>
<td>252</td>
<td>.39</td>
<td>-1.26</td>
<td>-4.16 – 1.64</td>
<td>-.06</td>
</tr>
<tr>
<td>Behaviour Regulation Index</td>
<td>-1.62</td>
<td>235</td>
<td>.11</td>
<td>-2.40</td>
<td>-5.31 – .51</td>
<td>-.12</td>
</tr>
<tr>
<td>Meta-Cognition Index</td>
<td>-.57</td>
<td>237</td>
<td>.57</td>
<td>-.87</td>
<td>-3.84 – 2.11</td>
<td>-.04</td>
</tr>
<tr>
<td>Global Executive Function</td>
<td>-1.77</td>
<td>148.8</td>
<td>.08</td>
<td>-2.43</td>
<td>-5.15 – .29</td>
<td>-.12</td>
</tr>
<tr>
<td><strong>C3</strong> ( (n = 44) ) v <strong>C4</strong> ( (n = 31) )</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total anxiety score</td>
<td>.23</td>
<td>72</td>
<td>.82</td>
<td>-.50</td>
<td>-3.93 – 4.92</td>
<td>.03</td>
</tr>
<tr>
<td>Major depressive disorder</td>
<td>-.75</td>
<td>70</td>
<td>.46</td>
<td>-1.89</td>
<td>-6.95 – 3.17</td>
<td>-.09</td>
</tr>
<tr>
<td>Behaviour Regulation Index</td>
<td>-.27</td>
<td>62</td>
<td>.79</td>
<td>-.64</td>
<td>-5.37 – 4.08</td>
<td>-.09</td>
</tr>
<tr>
<td>Meta-Cognition Index</td>
<td>1.01</td>
<td>64</td>
<td>.32</td>
<td>2.43</td>
<td>-2.38 – 7.23</td>
<td>.03</td>
</tr>
<tr>
<td>Global Executive Function</td>
<td>.06</td>
<td>64</td>
<td>.95</td>
<td>.15</td>
<td>-4.24 – 4.53</td>
<td>.01</td>
</tr>
</tbody>
</table>

*Note. 
*2-tailed significance. **Cohen’s \( d \) coefficient. †C1 v C2 refers to concussed versus non-concussed conditions; C3 v C4 refers to single versus multiple concussive injury conditions.

**Discussion**

The present study aimed to assess the impact of single and multiple medically diagnosed concussion on the emotional and cognitive functioning of adolescents, utilising both self- and
parent report measures. Over one quarter (29%) of the sample indicated they had sustained a concussion at some stage in their lives, which reiterates the significance of better understanding the possible ongoing complications of concussion on the developing brain. In accordance with Belanger and Vanderploeg (2005), Broglio and Puetz (2008), and McCrory et al. (2013), 93% of participants indicated that they had recovered from their concussion within 10 days, including 61% who believed they had recovered within 24 hours. To avoid self-report response bias, details of concussion history and recovery profile were compared against parent report data, with results indicating no significant difference between the two groups ($p > .01$). Further, the results of a between group analysis of the mean recovery time between early (11-13yrs) and later (14-17yrs) adolescence showed no significant difference. This finding contradicts previous research (e.g., Field et al., 2003; McCrea et al., 2003) which proposes a longer recovery profile for younger individuals. Notably, this finding should be interpreted with caution, as the concussion information collected was retrospective; as such, participants may have been considerably younger at time of injury.

Evaluation of academic performance and emotional and executive functioning in adolescents who had a history of concussion, compared to those who had never sustained a concussion, showed no significant difference. Furthermore, the findings of the present study also provide support for the null hypothesis that concussion may have a dosage effect on cognitive and emotional functioning. There were no significant differences identified in school grades, executive function, depression, or anxiety scores between adolescents who had experienced a single concussion, compared to adolescents who had sustained multiple concussions.

While the results of this study do contradict some of the existing literature on the long-term effect of concussion on the developing brain (e.g., Anderson et al., 2005; Guskiewicz et al.,
2004; McKee et al., 2009), it does add support to an emerging body of research. There have been several impact studies which have used traditional measures in addition to neuropsychological test batteries to identify enduring long-term complications following concussion which have found no association between the number of previous concussions and adolescents’ current performance on cognitive tasks such as motor function, decision making, attention, learning, and memory (Bruce & Echemendia, 2009; Collie, Iverson et al., 2006; Collie, McCrory, & Makdissi, 2006). The development of secondary symptoms have been raised as a concern in paediatric concussion (Eisenberg et al., 2014), however following a longitudinal study, Ettenhofer and Abeles (2009) reported that concussion does not result in cognitive impairment or psychiatric dysfunction in adolescence, even when follow-up testing was performed three years post-concussion.

Although children and adolescents who have had a single concussion may experience some long-term complications, it is rare that a single concussive event will produce enduring consequences (Belanger & Vanderploeg, 2005; McClincy & Lovell, 2006). Cognitive function can be affected by many factors other than the effects of concussion, such as pre-injury functioning, underlying psychopathologies (e.g., learning difficulties, ADHD), substance misuse (especially during late adolescence), level of education, cultural background, disrupted sleep patterns, anxiety, and normal developmental demands (e.g., changing roles, shifting priorities; Patel & Reddy, 2010). The theory of cognitive reserve has also been proposed as a possible explanation for differences in adolescent recovery patterns (Fay et al., 2010; Stern, 2002). That is, it has been suggested that individuals with higher cognitive abilities at baseline have better outcomes following head injury, as they may be able to recruit alternate and additional neural pathways to compensate for any tissue damage caused by concussion (Fay et al., 2010).
Consideration for this assertion reiterates the significance of individualised injury assessments and recovery profiles on regular baseline testing to account for confounding factors which may be impacting upon injury recovery and cognitive performance in a rapidly developing population.

**Conclusion**

The possible long-term consequences of concussion on cognitive and emotional functioning are a logical concern, especially in children and adolescents who are still undergoing rapid neurological development. The findings of this study, however, found no significant differences in school grades, executive function, depression, or anxiety scores between adolescents who had never experienced a concussion, compared to adolescents who had previously sustained neither a single nor multiple concussions. Although a large majority of participants indicated they had recovered from their injuries within seven to 10 days, the importance of a gradual return-to-play schedule should not be overlooked to avoid additional sub-concussive insult before the immature brain has recovered sufficiently. Further prospective research is needed to better clarify the cumulative effects of concussive injury as it pertains to neuropsychological recovery from injury, attenuation in academic performance, susceptibility to post-concussion syndrome, and potential influences on long-term neurological functioning from an individual perspective.

**Limitations.** Both the cross-sectional methodology and restricted sample size limited the findings of the present study. As this study comprised a cross-sectional design, the non-significant interaction between concussion and cognitive and emotional functioning cannot imply causality (or lack thereof). The cross-section of participants was also limited, as athlete’s current age may not be comparable to the age they were when they sustained a concussion (i.e., 14 year
olds may have been 12 years old at time of injury). Other notable timing discrepancies include
the assessment of retrospective concussion data against present day emotional and cognitive
function evaluation. The long-term effect of sustaining a concussion on normative development
remains a significant gap in research; which should be addressed with a robust prospective or
longitudinal research design to avoid Type I error.

A further limitation of the present study was the restricted sample of single and multiple
medically reported concussions. Of the total 75 participants who reported having sustained a
concussion, only 31 cases had experienced more than one concussion in their lives; thus
statistical analyses of this limited sample may invite Type II error. Similar to the two earlier
studies in this project, the participant sample in this study were also largely homogenous on their
scores of cognitive and emotional functioning as reported by both themselves and their
guardians. This study therefore was not able to assess the impact of concussion on participants
who may have underlying pathology. As previously mentioned, these limitations may be
addressed in future research by broadening the sampling criteria to include other team sports.
Chapter Six – A Sociotechnical Systems Approach to Understanding how Sport-Related Concussion is Prevented, Identified, and Treated in Community Rugby Union

Despite growing awareness of the issue of sport-related concussion, the extent to which different participants in rugby union (e.g., players, coaches, parents, medics, referees) understand how to identify, prevent, or treat concussion is unclear. There have been numerous and varying guidelines, consensus statements, and position standings developed by different organisations and associations (for review see West & Marion, 2014); these have led to inter-sport, and even inter-club, variability in the sideline treatment and management of concussion. The management guidelines developed following the concussion in sport (CIS) consensus conference (known as the ‘Zurich Guidelines’; McCrory et al., 2013) have been adopted and endorsed widely amongst professional sporting bodies, including the International Rugby Board (IRB) and Australian Rugby Union (ARU). The extent to which these guidelines are then disseminated and implemented in amateur and community sport remains scarce (Finch, McCrory, Ewing, & Sullivan, 2013; Hollis et al., 2012).

Considering the Context

In previous research there has been minimal consideration for the broader contextual and social factors that influence how rugby participants receive concussion prevention and management guidelines, or their perceived relevance and value. Donaldson and Finch (2011) suggest that the lack of success in getting the correct information to end-users (e.g., players, coaches, parents, medics etc.) may be due to the reliance on the publication of sport injury prevention strategies in peer-reviewed journals, which are mostly from a clinical perspective. Context sensitive, sport-specific safety management capacities and structures need to be identified to better facilitate the agreement, implementation, and maintenance of evidence-based
injury prevention interventions (Donaldson & Finch, 2011; Finch et al., 2013). That is, to optimise the dissemination of injury prevention strategies, there needs to be a better understanding of how athletes, coaches, administrators, and volunteers perceive and interpret concussion management guidelines within their sporting culture and real-world context.

**Current Prevention Strategies in Rugby Union**

There have been numerous prevention strategies developed aimed at preventing sport-related concussion in rugby. These strategies have included the avocation of protective wear, rule adaptations, and sport-specific education programs.

**Headgear.** In rugby, players have the option of using headgear, mouthguards, and other thin-padded body shields for protection against injury (IRB, 2014). One of the most common misconceptions held by rugby participants, including players and coaches, is that wearing headgear can prevent concussion (Finch, McIntosh, & McCrory, 2001; Valovich-McLeod, Schwartz, & Bay, 2007; White et al., 2013). This was illustrated in a study of under 20 year old rugby players, 45% of whom believed that headgear was protective against concussion (Baker et al., 2013). Similarly, over 52% of coaches and 41% of trainers believed that headgear could help prevent concussion in community football (White et al., 2013). Rugby headgear, or ‘scrum caps’, are made of soft polyethylene foam padding with no hard outer shell, and its use is not mandatory. Consequently the effectiveness of headgear in preventing concussion has been able to be studied prospectively, which McIntosh and McCrory (2001) did in a study of 294 under 15 year old rugby players. Over the course of the study, there were 30% more exposures to head contact in players wearing headgear compared to those without headgear. These findings suggest that headgear may increase a player’s incidence of concussion (McIntosh & McCrory, 2001). Finch et al. (2001) and Hollis et al. (2009) suggested that this may be due to players
experiencing increased feelings of protection when wearing protective equipment, which may prompt them to play more aggressively and/or recklessly.

**Mouthguards.** Mouthguards are another widely recommended piece of protective equipment for football players. While mouthguards may provide protection against orofacial injuries in rugby (Knapik et al., 2007), studies on the efficacy of mouthguards in preventing sport-related concussive injury have been largely non-significant (Cusimano, Nassiri, & Chang, 2010; Gardner et al., 2014; Knapik et al., 2007). For example, no significant effect of mouthguards on the incidence of concussions was found in a prospective study of 304 male rugby players, who were followed weekly over the course of a club season (Marshall et al., 2005). Irrespective of these inconclusive results, in two separate studies Brahams et al. (2004) and Finch et al. (2005) found that almost three quarters of a sample of community football players reported wearing mouthguards, with injury prevention and safety as the common motivating factor. Furthermore, 40% of rugby players consider mouthguards or gum shields as protective against concussion (Baker et al., 2013). Although developed to aid in preventing rugby-related concussion, evidence supporting the effectiveness of mouthguards and headgear in preventing concussion is limited (Cusimano, Nassiri, & Chang, 2010; Gardner et al., 2014). The current lack of an evidence base supporting the effectiveness of mouthguards in preventing concussion limits the safety advice that can be given to players or their parents, coaches, and sports administrators.

**Rule adaptations.** Intentional head-high contact has been illegal in rugby since its conception in the mid-1800s, however over 85% percent of head injuries in rugby are actually due to collisions or impacts with other players (e.g., during tackles/scrums; Cusimano et al., 2013). McIntosh and McCrory (2005) identified high tackles, high velocity impact, peripheral
collisions, multiple-player tackles, and poor tackling skill as the actions most often responsible for concussive injury in rugby. In a study of attitudes and behaviours towards tackling during training and competition, adolescent rugby players ($M = 17$ years, $SD = .8$) were found to place more value on performance than injury prevention (Hendricks, Jordaan, & Lambert, 2012). Players reported that “bringing down the ball-carrier at all costs”, “preventing the ball-carrier from gaining position”, “preventing the ball-carriers team from retaining the ball”, and putting in a “big hit” were most important to them when executing a tackle during a match. “Doing what was practiced”, “your own safety”, and “safety of the ball carrier”, were considered of least importance. Players also indicated that coaching method, especially one-on-one and team demonstrations, influenced their tackling technique, attitude, and behaviours; and that personal conditioning, determination, and motivation were most likely to improve their tackling performance (Hendricks, Jordaan, & Lambert, 2012). This provides an illustration of the impact of multiple system levels on young players’ safe tackling behaviours; namely individual beliefs, coaching style, and culturally influenced health beliefs. With the exception of high tackles and spear tackles (i.e., where the ball carrier is speared head first into the ground), all other types of tackle are legal for athletes aged 8 years and up (IRB, 2014). In an attempt to moderate the risk of concussive injury in rugby, the IRB has adapted the laws of the game to minimise head impact during play, particularly for players under 19 years of age (IRB, 2014). In youth rugby (under 9 to under 19 year olds), rule modifications include changes to the size of the field, the duration of the game, team numbers, and scrum and lineout engagement.

These factors may not prevent concussion risk directly, however they do facilitate different styles of play between age grades (Haseler, Carmont, & England, 2010). For example, rolling substitutions are encouraged in junior games to promote fun and equal playing time; with
more focus on player development than competition. This is reflected in junior law changes regarding scrum engagement and the speed of lineouts (e.g., if the setup for a scrum or lineout is not right, the referee awards possession to the attacking team, so the players can “get it right”; ARU, 2014). Designed to minimise sport-related injury risk, the adaptations for junior rugby take differences in maturation and ability into consideration. In comparison, adolescent athletes tend to be more competitive and performance focused, with players less likely to use substitutes in an attempt to optimise gameplay. Consequently games are often faster and more aggressive, with game laws for 15 to 19 year olds allowing for full contact (e.g., lifting at lineouts, as well as contested scrums, rucks, and mauls; ARU, 2014). Despite being widely viewed as successful, minimal research has been done to assess the efficacy of rule changes on preventing concussion and head injury in junior rugby. Furthermore, it is unclear how consistently the adapted game rules are implemented and enforced, especially in community rugby which characteristically rely on the support of volunteer staff (Collins, Fields, & Comstock, 2008; Hollis et al., 2012; Shuttleworth-Edwards et al., 2008).

**Education programs.** Aimed at reducing the frequency of high-risk behaviours in sport, numerous rugby-specific educational injury programs promoting proper playing techniques and enforcement of game rules have also been developed; for example *Rugby Ready* (IRB), *Rugby Smart* (New Zealand), *Bok Smart* (South Africa), and *Smart Rugby* (Australia). Smart Rugby is the ARU’s health and safety program designed to provide information on common rugby injuries and prevention strategies; technique and best practice advice; and injury management and protocol, including a specific concussion management module (ARU, 2014). Based on the CIS guidelines (McCrory et al., 2013), the concussion management module aims to inform clubs, coaches, support staff, match officials, as well as players and their parents about the prevention,
identification, and management of rugby-related concussion through the ‘6Rs’; Recognise, Remove, Refer, Rest, Recover, and Return (see ARU, 2014). As with assessing the implementation of rule adaptations, evaluating the effectiveness of concussion prevention education programs is made difficult by variations and limitations of the infrastructure in amateur and community rugby.

Following an evaluation of New Zealand’s Rugby Smart program, Gianotti, Quarrie, and Hume (2009) concluded that community based injury prevention programs are successful in reducing sport-related injury, however determining national exposure for community level injury prevention across multiple grades and competitions is impeded by the absence of a unanimous agreement on both definitions of injury and the baseline incidence of sport injury. More research is required to establish whether the implementation strategies employed by injury prevention programs is being effectively translated to- and adopted by all role players in rugby.

Sport-related injury prevention in community rugby, in the form of implementing and enforcing prevention strategies, is noted as being more often the role of club management, coaches, or other support staff (rather than the players themselves; Hollis et al., 2012). Strategies aimed at preventing the incidence of sports-related concussions in community rugby are a positive and proactive development, however the paucity in their effectiveness in preventing sport-related concussive injury illustrates how multi-faceted the issue of concussion is in team contact sport. It is the unfortunate reality that concussion may be an inevitable incident in contact sports where unintentional head impact is a recognised part of the game. In these sports, the identification of concussions and managing post-concussion events become key considerations.
Identifying Sport-related Concussion in Rugby Union

Concussion can be caused by either a blunt trauma to the head (e.g., head collision) and/or the rapid acceleration or deceleration of the neck and head produced by ‘whiplash’ force (e.g., body tackle; McCrory et al., 2013; Ommaya et al., 2002). The recognition and identification of concussion is consistently noted in literature as being the most challenging aspect of sport injury management. These challenges arise out of discrepancies in injury definition and symptom recognition (Gardner et al., 2014), as well as inconsistencies in sideline protocol, such as use of screening tools and unclear role responsibilities (Cohen et al., 2009; McKeever & Schatz, 2003).

Differential definitions. A recurring issue in literature regarding the definition of concussion is whether it represents as a linear spectrum of injury severity (i.e., graded sub-types of concussion) or whether it should be considered a single entity (i.e., present or absent; Lovell et al., 2004; Makdissi, 2009; McCrory et al., 2013). Following review, it has been recommended that the use of grading scales be abandoned, as no single grading system adequately addresses the multiple facets of sport-related concussion (Makdissi, 2009; McCrory et al., 2013). For example, the commonly used grading system suggested by Kelly and Rosenberg (1998), which was based on practice parameters set by the American Academy of Neurology, proposed a diagnosis of a low grade concussion (‘a light ding’) if the athlete only had transient confusion and did not lose consciousness. The cognitive disruption following a low grade concussion was assumed to resolve within 15 minutes, allowing athletes to return to play on the day of injury. This assumption was critically challenged by data indicating that concussion symptoms in junior athletes may not be immediately present following an impact, instead developing over time (Echemendia et al., 2001; Lovell et al., 2004). Consequently the use of several individual
systematic evaluations are now recommended to assist in the sideline identification and diagnosis of concussion (McCrory et al., 2013).

**Recognising the symptoms.** There have been many different sport-related approaches to identifying and managing concussion in the past decade (e.g., Aubry et al., 2002; Guskiewicz et al., 2004; Harmon et al., 2013; McCrory et al., 2005, 2009; 2013). Although most of these approaches do offer guidance in identifying the signs and symptoms of concussion, it is often general guidance with minimal consideration for the possible effect of individual variables (e.g., age, gender) on symptom presentation (Finch et al., 2013; Kirkwood, Yeates, & Wilson, 2006). Nevertheless, the more common symptoms of concussive injuries appear to be comparable for junior and adult athletes, namely reduced speed of information processing, poor attention, and impaired executive function (Anderson, 2003; Makdissi et al., 2013; McCrory et al., 2005). In high school athletes, headaches have been found to be the most commonly reported symptom of concussion; described as a sensation of pressure which is often worse during physical or cognitive exertion (Gessel et al., 2007). Confusion, dizziness, drowsiness, and visual disturbances are also frequently reported symptoms of junior sport-related concussion (Cohen et al., 2009).

The Sideline Concussion Assessment Tool, Revised (SCAT2), has become one of the most widely used sport-related concussion assessment tools (Guskiewicz et al., 2013; McCrory et al., 2013). It was developed following the International Conference on Concussion in Sport as a measure for evaluating injured athletes (aged 10 years and older) for concussion (McCrory et al., 2005, 2009, 2013). The SCAT2 is used for sideline and clinical assessment of concussion by determining a combination of scores from the number of symptoms and severity of symptoms; physical signs of loss of consciousness and/or balance problems; Maddocks’ assessment of
orientation (Maddocks, Dicker, & Saling, 1995); immediate memory, concentration, and delayed recall (i.e., the Standardized Assessment of Concussion; SAC; McCrea, 2001); and a coordination examination (e.g., finger-to-nose; McCrory et al., 2009). The purpose of this measure was to offer a standardised field-side assessment tool that can be used to systematically identify a concussive injury as soon as possible, however to be effective an athlete’s pre-injury functioning needs to be recorded (Borich et al., 2013; Valovich-McLeod et al., 2012; McCrory et al., 2005, 2009, 2013).

In a large epidemiological study investigating representative SCAT2 baseline values for adolescents, healthy athletes were found to display significant inter-individual variability in their scores (Valovich-McLeod et al., 2012). This illustrates the need for personal pre-season baseline functioning to be taken regularly, especially while rapid neurological and physical developmental changes are occurring, such as during the ages of 5 and 15 years (Makdissi et al., 2013; Valovich-McLeod et al., 2012).

**Baseline evaluation.** During these ages of development it is recommended that junior athletes have their baseline functioning assessed every six months to enable accurate comparison if they were to sustain a concussion (Borich et al., 2013; Valovich-McLeod et al., 2012). Unfortunately regular baseline screening is often reported to be beyond the resources of some sporting clubs, which are largely run on a volunteer basis, as is often the case in youth and community sport. Consequently, young athletes playing in amateur and community teams may not receive regular pre-season medical screening as they are less likely to have formally trained medical professionals who are knowledgeable about concussions available at training and game events (Borich et al., 2013; Cohen et al., 2009; Makdissi et al., 2013). The type of advice provided by coaches and support staff about identifying and managing concussion has been
found to vary considerably across community rugby union clubs (Hollis et al., 2012),
nevertheless non-healthcare personnel such as a coach, parent or spectator are often the first to
identify a sports-related concussion (Cohen et al., 2009; Gardner et al., 2014). Conversely, in a
study exploring adolescent rugby players’ understanding of concussion, the majority of
respondents stated that following a sport-related concussion, they would make decisions about
their diagnosis and return to play themselves (Sye, Sullivan, & McCrory, 2006).

Identification responsibilities. The paucity in between-role concussion identification
knowledge has been demonstrated consistently in research. For example, Valovich-McLeod,
Schwartz, and Bay (2007) found that 42% of junior coaches believed a concussion only occurs
when an athlete loses consciousness, with 25% indicating that they would allow the athlete to
return-to-play on the same day of injury. A knowledge deficit was also observed regarding the
recognition of sport-related concussion between youth athletes and their parents, who were only
able to answer 3 out of 5 true-or-false questions assessing sport-related concussion recognition
and management (Gourley, Valovich-McLeod, & Bay, 2010). Under identification or delayed
identification of a concussion may, therefore, be more likely in youth sports consequent of
misunderstandings or inconsistent information disseminated within different roles (Cohen et al.,

Identification of rugby-related concussion is further complicated by athletes under-
reporting or down playing the severity of their injuries. In rugby, underreporting is motivated by
lack of awareness of a probable concussion, players not thinking concussion was a serious injury,
and/or not wanting to be withheld from participation (Hollis et al., 2012; Gardner et al., 2014;
Sye, Sullivan, & McCrory, 2006). Together each of these challenges complicate the effective
treatment of sport-related concussion, particularly in amateur and community-based teams, where education and infrastructure may be inconsistent or limited.

**Treatment and Post-Injury Management of Rugby-Related Concussion**

Most symptoms of sport-related concussion resolve within seven to 10 days, however evidence has suggested that younger athletes take longer to recover and are more susceptible to adverse and ongoing effects of concussion, compared to older athletes (Field et al., 2003; McClincy et al., 2006; McCrory et al., 2013; Sim, Terryberry-Spohr, & Wilson, 2012).

**Age sensitivity.** High school aged athletes in particular have been found to experience prolonged disruptions to memory, reaction time, and processing speed (Field et al., 2003). In a prospective case control study, high school athletes performed significantly worse than age-matched controls at seven days post-injury, in comparison to college athletes showed who had recovered within three days (Field et al., 2003). Similarly, Simm, Terryberry-Spohr, and Wilson (2012) found memory dysfunction was evident in high school athletes up to 10 days following a sport-related concussion. Irrespective of the underlying mechanisms resulting in these apparent age-related differential responses to concussion not being completely understood, most concussion management guidelines call for more conservative treatment and progressive return to play for young athletes (ARU, 2014; IRB, 2014; McCrory et al., 2013).

**Remove from play.** The response advice proposed in the concussion management guidelines developed by the CIS calls for the immediate removal of athletes from play if a concussion is suspected (McCrory et al., 2013). Further, the ARU (2014) along with the IRB (2014) propose a 3-week break from participating in both training and competition following a head injury causing concussion, which is mandatory for players younger than 18 years old. Although intended to protect young players, this ‘stand-down’ rule may discourage athletes from
seeking treatment and suppress the reporting of symptoms associated with concussion (Gardner et al., 2014; Marshall & Spencer, 2001). In addition, it should be noted that this recommendation was developed based on general consensus rather than empirical evidence. In fact, over one third of adolescent athletes will still exhibit neurometabolic disruption up to one month after sustaining a concussion (Moser, Glatts, & Schatz, 2012), suggesting that junior athletes may require more than three weeks to fully recover.

**Physical and cognitive rest.** Rest is considered to be the cornerstone of concussion management, however the published evidence regarding the function of rest following a sport-related concussion is sparse (McCrory et al., 2013). Nevertheless, most consensus statements and guidelines for treating concussion propose that, following a head injury an athlete should have complete physical and cognitive rest until completely asymptomatic (ARU, 2014; IRB, 2014). That is, sporting participation or training, physical education classes, or even physical play with friends or siblings, should be avoided. Cognitive rest should also involve limiting activities that require mental exertion, including gaming, texting, watching television, computer work, reading, and school work (Purcell, 2009). A recent study of high school athletes showed that cognitive and physical rest, both immediately after injury and later during recovery, decreased symptoms of concussion and improved performance on computerised neuropsychological tests (Moser, Glatts, & Schatz, 2012).

**Return-to-play.** Once symptoms begin to recede, a step-wise return to activity is recommended in the CIS guidelines, beginning with light exertion and slowly rehabilitating to sport-specific activities (McCrory et al., 2013). This gradual return to play (GRTP) has since been adapted by the ARU (2014). Under the ARU guidelines, players under 18 years old are prohibited from returning to contact training or competition for at least two weeks after all
concussion symptoms have ceased and are required to obtain formal medical clearance before they can commence the first stage of return. This ‘one size fits all’ approach to concussion management in junior rugby overlooks the recommendation that injured athletes should be assessed and managed on an individual basis, consequent of the variability in concussion symptomology and recovery time in younger athletes (Finch et al., 2013; McCrory et al., 2013; Purcell, 2009). This may place pressure on multiple levels of the community rugby system. For example, players may be discouraged from reporting their injury to avoid being removed from play; coaches may be less inclined to implement the guidelines to prevent losing players; and parents may be sceptical about enforcing the recommended absence from school activities.

Considerable inconsistencies have been noted in literature regarding the implementation and enforcement of GRTP. In a sample of Australian rugby players, Hollis et al. (2012) found that 78% of players who experienced (or suspected) a concussion failed to receive return-to-play advice and those who did receive the correct advice failed to comply with regulations anyway. Junior rugby coaches’ knowledge and utilisation of concussion guidelines has also been found to be inconsistent, with one study finding that 23% of community coaches were either unaware or unsure of the ARU’s prescribed concussion treatment guidelines (Finch et al., 2013). Furthermore, following an online survey it has also been found that up to 46% of Australian general practitioners (84% of whom had diagnosed/managed patients with a sport-related concussion) are not aware of any specific guidelines for the diagnosis or management of sport-related concussion (Zonfrillo et al., 2012). Trends such as these suggest that the current sideline treatment and return-to-play guideline revisions are not being reliably implemented in junior and amateur sport. This illustrates the need to query the attitudes regarding the implementation and
enforcement of concussion management guidelines from a broader system perspective, with consideration for the specific ecological structure and context of community rugby.

**Understanding Rugby-Related Concussion from a Systems Perspective**

The impact of the current sport concussion guidelines on actors’ knowledge, attitudes, and behaviours toward concussion requires system-wide evaluation within a community rugby context. Numerous studies have demonstrated that physician, trainer, coach, parent, and athlete attitude and behaviour regarding the prevention, identification, treatment of concussion is lacking in consistency and accuracy (see Donaldson et al., 2014 for review). As an individual’s behaviour is a function of the interactions between people and their immediate, social, and organisational environments (Donaldson & Finch, 2011; Provvidenza et al., 2013), current knowledge and understanding of concussion identification and management needs to be reviewed from a systems perspective. Systems thinking approach to accident causation is a long and established philosophy that has evolved through a number of accident causation models (e.g., Leveson, 2004; Perrow, 1984; Rasmussen, 1997). The philosophy has evolved to a point where overall systems comprising government, regulatory bodies, organisations, individuals, technologies, documents, and the environment becomes the unit of analysis when tackling safety issues (e.g., Rasmussen, 1997). Accordingly, systems thinking argues that safety, and indeed accidents and injuries, are emergent properties arising from non-linear interactions between multiple components across overall systems (e.g., Leveson, 2004; Salmon et al., 2016).

One popular systems-based model of accident causation, Rasmussen’s (1997) risk management framework, is currently receiving significant attention in injury prevention in sport and outdoor recreation (e.g., Clacy et al., 2015; Dallat, Salmon, & Goode, 2015; Goode, Salmon, Finch, & Lenne, 2015; Marras & Hancock, 2013). The framework is underpinned by the idea...
that systems comprise of various levels (e.g., government, regulators, company, company management, staff, and work), each of which are co-responsible for safety. With regard to injury, the framework argues that safety and injury events are created by the decisions of all actors, not just the front line participants in isolation, and accidents are caused by multiple contributing factors, not just one bad decision or action. In the concussion context, this approach would argue that there is a shared responsibility for concussion that spans players, clubs, sporting agencies and government amongst others.

Within contact sport environments (i.e., high risk environments) head impacts and injuries occur frequently, thus are not considered abnormal. This has led to the development of concussion management strategies (e.g., McCrory et al., 2012) that are based on assumptions about the mechanisms of injury rather than the system-wide factors which may influence injury risk. Although Rasmussen’s framework was developed to better understand the mechanisms underpinning large scale, high risk accidents (e.g., “freak” accidents which occur due to the loss of control in an otherwise controlled system), Goode et al. (2014) demonstrated that this framework can also be applied to more frequent accidents which occur in repetitive task settings where the conditions at the time of injury are unlikely to be considered abnormal.

The authors therefore argue that Rasmussen’s risk management framework provides a suitable model for examining concussion prevention and identification in rugby. Firstly, given that injury management decisions, actions, and system performance at all levels of a system are interactive (Rasmussen, 1997; Rasmussen & Svedung, 2000), applying systems thinking to concussion management provides a framework for examining the system of actors and agencies that potentially share the responsibility for concussion identification and treatment. Secondly, it provides a way of representing the various levels of influence within the system and considers
concussion identification and treatment as an emergent property arising from the interactions between actors within the system. In turn this will enable identification of the system wide factors influencing concussion identification and treatment. Thirdly, like with many community-based sports, the amateur leagues of rugby are delivered through a network of local clubs. Behind this network, rugby is administered in a hierarchical manner within an international, national, state/provincial and regional structure (World Rugby, 2015). By applying Rasmussen’s framework, non-linear interactions may be able to be identified, thus better informing the translation and dissemination of influencing factors, concussion knowledge, and management strategies throughout the rugby system. The development of a proactive approach to concussion management requires a consideration of the factors that shape decision-making and behaviour in the sport context, as well as an understanding of the hazards inherent to the activity (Rasmussen & Svedung, 2000). Therefore Rasmussen's framework provides a means of integrating these perspectives in order develop an overall picture of the factors influencing the concussion management strategies of all actors within the rugby system.
**Research Aims**

Given that the interactions between different members of the rugby system are likely to influence the individual characteristics and behaviours of young athletes (Donaldson & Finch, 2011; Provvidenza et al., 2013), these factors should be considered within the context of the sporting system in which they occur. Therefore, the aim of the final study in this research project was to utilise a systems framework to explore how people within different roles prevent, identify, and treat sport-related concussion in community rugby union. Qualitative responses from players, coaches, parents, medics, volunteers, referees, management and administration (actors) were assessed for gaps and overlaps in knowledge between roles and against the rugby-adapted CIS guidelines (e.g., ARU, 2014; IRB, 2014).
Method

Participants

Participants were 107 members of the community rugby union system (69.2% male), who were either presently or previously directly involved with the sport (i.e., are or were active participants within the community rugby system). Respondents ranged in ages from 15 to 75 years ($M = 34.8$, $SD = 13.0$), and had been involved with rugby for an average of 15.2 years ($SD = 12.9$). Over half of the sample had either an undergraduate or postgraduate degree (31.5% and 33.3%, respectively); 22% had a high school education (or were still in high school). The majority of respondents (40.2%) identified as being primarily a ‘player’; additionally, ‘coach’, ‘parent’, and ‘medic’ each comprised ~15% of the sample. The demographics of respondents within different roles are displayed in Table 12. Thirty-five participants (32.7%) indicated having more than one role in rugby; only the primary and secondary roles were recorded (see Table 12).
### Table 12. Participant Information

<table>
<thead>
<tr>
<th>Primary Role</th>
<th>Distribution</th>
<th>Age (years)</th>
<th>Experience (years)</th>
<th>Secondary role (n*)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>%</td>
<td>%♂</td>
<td>Range</td>
</tr>
<tr>
<td>Player</td>
<td>43</td>
<td>40.2</td>
<td>74.4</td>
<td>15-44</td>
</tr>
<tr>
<td>Coach</td>
<td>16</td>
<td>15.0</td>
<td>93.8</td>
<td>25-57</td>
</tr>
<tr>
<td>Parent</td>
<td>17</td>
<td>15.9</td>
<td>41.2</td>
<td>42-75</td>
</tr>
<tr>
<td>Management</td>
<td>2</td>
<td>1.9</td>
<td>50</td>
<td>34-42</td>
</tr>
<tr>
<td>Medic</td>
<td>17</td>
<td>15.9</td>
<td>52.9</td>
<td>22-63</td>
</tr>
<tr>
<td>Admin</td>
<td>5</td>
<td>4.7</td>
<td>80</td>
<td>40-52</td>
</tr>
<tr>
<td>Volunteer</td>
<td>2</td>
<td>1.9</td>
<td>100</td>
<td>29-54</td>
</tr>
<tr>
<td>Referee</td>
<td>5</td>
<td>4.7</td>
<td>80</td>
<td>20-37</td>
</tr>
</tbody>
</table>

*Note. %♂ Percentage of the sample that were male. * Number and role of participants who identified as having a secondary role in rugby.*
Measures

Applying systems theory. Using Rasmussen’s framework, the identification and treatment of sport-related concussion in community sport can be considered within a hierarchy. Using this framework governing bodies (e.g., IRB, ARU); regulatory bodies, such as schools and state clubs; regional clubs (e.g., regional club presidents, club members); immediate supervisory group, including coaches, parents, and referees etc.; activity participants (e.g., players, spectators, match officials); and equipment and surroundings, such as the field conditions and safety equipment were considered as components of the system (see Figure 3 in which the local Queensland community rugby system were mapped onto Rasmussen’s framework). To ensure that all levels of the system were included in the study, local rugby union coordinators, management, and coaches contributed and gave feedback on the adaptation of the model. It should be noted that role multiplicity (i.e., players may also be parents; coaches may also hold managing roles at the regional level) is common in community sport, and was addressed by asking participants to identify their primary and secondary roles within the rugby.

Role specific data. Participants were asked open-ended questions about what their role-specific strategies and responsibilities were in preventing, identifying, and treating sport-related concussion (see appendix 5). To ensure responses were comprehensive and captured all aspects of actors’ perceived roles and responsibilities in concussion management, role-specific questions were structured as per Theory of Reasoned Action (TRA; Ajzen, 1985; Godin & Kok, 1996). TRA posits that a person’s intention to perform or not perform a behaviour is an immediate determinant of that action. As such, participants were asked about both their perceived role-specific responsibilities as well as their actual behaviours and/or strategies (see Table 13). In addition to demographic questions (e.g., age, years of
involvement, primary and secondary role in rugby), participants were also asked from where they believed they had received most of their concussion-related knowledge.

Table 13. Role specific questions regarding concussion prevention, identification, and treatment.

<table>
<thead>
<tr>
<th>Preventing concussion</th>
<th>1. In your role, are you involved in preventing concussion?</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2. In your role, what are you responsibilities in preventing concussion?</td>
</tr>
<tr>
<td></td>
<td>3. How would/do you prevent concussion?</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Identifying concussion</th>
<th>1. Are you able to identify a concussion/symptoms of a concussion?</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2. In your role, what are you responsibilities in identifying concussion?</td>
</tr>
<tr>
<td></td>
<td>3. How would/do you identify concussion?</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Treating concussion</th>
<th>1. In your role, are you involved in treating concussion?</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2. In your role, what are your responsibilities in treating concussion?</td>
</tr>
<tr>
<td></td>
<td>3. How would you/do you treat a concussion?</td>
</tr>
</tbody>
</table>

Procedure

Ethical approval was obtained from the University of the Sunshine Coast (S/14/662). The questionnaire was developed as an online survey using SurveyMonkey, and trialled on a small selection of different actors ($n = 20$) before being distributed to the study cohort. The survey was distributed online at the conclusion of the 2014 rugby season (October – November). Invitations to participate were sent via email to regional Australian rugby teams and their associated members (e.g., local referees and team medics). Invitations were also sent to the wider rugby community through social media (e.g., Twitter, Facebook) and local newspaper and televised media. Informed consent was obtained from all respondents before
the survey began. Participants under 16 years old were instructed to obtain parental consent before they could complete the survey. All participants were informed that participation was voluntary and responses would remain anonymous (see appendix 6).

Responses were extracted from SurveyMonkey and initially analysed using NVivo qualitative data analysis software, version 10. Using this software, qualitative responses were analysed thematically (adapted from Braun & Clarke, 2006) and coded into common themes (nodes), with separate coding for prevention, identification, and treatment domains of concussion awareness. To ensure responses were coded consistently, and that the resulting nodes were distinct from each other, data were analysed and coded twice by two different researchers. Any coding discrepancies were discussed with a third researcher until consensus was reached. Any alternate responses presented by participants with multiple roles were recorded as separate responses under a new participant number \( n = 11 \); adding a supplement of 7 player responses, and 1 response each for coaches, parents, volunteers, and referees. Frequency matrices were then generated for the number of times each theme was mentioned within each different role.

**Results**

According to the Theory of Reasoned Action (Ajzen, 1985; Godin & Kok, 1996), an individual’s intentions will precede their actual behaviour; thus it is important to consider both the actions people perform, as well as what they believe they ‘ought’ to do (e.g., their perceived responsibilities). As such, role-specific responsibilities and behaviours were thematically analysed separately within each domain of concussion awareness (i.e., prevention, identification, and treatment; see Figure 4).

**Thematic Analysis of Role-Specific Concussion Prevention Responsibilities in Rugby**

Sixty-two respondents (52.5%) indicated that, within their role, they were involved in preventing concussion. Coaches most consistently identified a role in preventing concussion
(14 of the 17 coaches answered affirmative), followed by first aid/medics (12/17), and parents (11/18). Although players comprised the largest portion of prevention responses, only 17 of 50 players (34%) believed they were involved in preventing concussion.
Figure 3. Application of Rasmussen's risk management framework illustrating the hierarchical organisation of the community rugby union system.
Figure 4. Thematic analysis of qualitative responses using a SE framework.
Coaches. The strongest themes coaches saw as their responsibility in preventing concussion were ‘training properly (e.g., strength, conditioning)’ and ‘teaching/correcting technique’, especially regarding tackling.

“Coaching correct technique in contact - zero tolerance for high tackles”

“Teach kids correct tackling techniques and placement of head and neck in contact situations.”

“…coach correct technique, identify and correct poor technique keep contact low (shoulders and below).”

“…assisting players in strengthening musculature around the neck, correct technique education.”

Many of the coaches also believed they had a responsibility educating themselves, their players, and also their players’ parents. Coaches emphasised the importance of learning how to identify a concussion, as well as increasing awareness in players and their families about the symptoms and dangers of concussive head injury. Providing a safe environment was another responsibility presented by two respondents, with consideration for both the environment as well as interpersonal risk;

“Ensure athletes are technically competent to play the game. Ensure athletes are presently fit to play. Maintain control of athletes who have potential to become overly aggressive or place others at risk.”

Only one coach mentioned he had a responsibility to encourage his players to wear “suitable protective gear”, as part of a comprehensive response which also included increasing concussion awareness, teaching good technique, and progressive introduction to the sport of rugby. When asked how they would prevent a concussion, coaches maintained a focus on correcting technique and education. Other coach-specific prevention behaviours included encouraging the use of headgear (n = 1), playing age appropriate teams (n = 1), and
safe return to play to reduce future concussions \((n = 4)\). Concussion prevention was presented by the coaches as a collaborative effort involving medical personnel and parents;

“During a match, make sure medical staff are aware if a player is showing potential concussion signs.”

“Report to parent, doctor and other coaches. Refer to doctor.”

“Player education, follow up with medical staff...”

Overall, coaches’ prevention beliefs and behaviours were largely homogenous. In accordance with the Theory of Reasoned Action, many of the coaches’ perceived responsibilities informed their actual behaviours in preventing concussion in rugby.

**Players.** ‘Using proper tackling technique’ and ‘playing safely’ were the prevention responsibilities identified by the majority of rugby players. Although safety was a consistent theme, players’ responses were vaguer than the coaches’; for example, one athlete stated their responsibility in concussion prevention was to “not get myself concussed”; another respondent stated that his responsibility was to “not give them [a concussion] to people.”

Two respondents believed they had a responsibility to ‘wear protective headgear’ in conjunction with ‘tackling appropriately’. Players also felt they had a responsibility to become “educated early”, “understand what concussion is”, and “raise awareness of concussion symptoms”, for their own safety as well as their teammates.

Interestingly, female players’ responses \((n = 4)\) regarding preventing concussion were all focused on education and wearing protective gear, whereas males presented more technique based responses. Playing by the laws of the game was proposed by several respondents as a role-specific prevention strategy; “As a player we can limit head injuries by learning the rules of the game and safe and appropriate contact techniques.” Players highlighted the importance of learning and abiding by the game rules to keep play as “safe as
possible.” This was mostly centred on practicing and utilising safe contact methods and using proper tackling techniques;

“Proper body position in rucking, tackling and set piece play.”

“Practice safe playing techniques with contact, practice engagement movements at training.”

“Tackling legally, not punching anyone.”

“No high tackle…use proper technique to protect myself.”

Over 41% of players proposed ‘wearing protective gear’ as a prevention strategy specific to their role, namely mouthguards (a.k.a., gum shields; \( n = 4 \)) and headgear \( (n = 3) \). Conversely, one player noted that “headgear has been proven to have no effect on reducing concussion.” Further stating that it is difficult to “prevent” a concussion in rugby. This opinion was shared by two other players who stated “what can you do?”; “you can never predict it [concussion], rugby is a contact sport”.

Players seemed less confident than coaches about their ability to prevent concussion within their role. This was illustrated through both direct statements, and indirectly through the paucity and vagueness in their responses. As attitudes towards a behaviour predict the likelihood of that behaviour occurring and being maintained (Ajzen, 1985), this finding may offer some explanation for the discrepancies and issues observed in the operational efficacy of intervention strategies in community rugby (e.g., Hollis et al., 2012).

**Parents.** Over half (61%) of the parents in the study identified as having a role in preventing concussion. Providing their child with protective gear, and encouraging its use, was the most common prevention responsibility presented by parents; with headgear being mentioned specifically by four respondents. Having an active role in their child’s training and gameplay was another strong theme in parent responses, including having a responsibilities in “researching and asking coach teaching style of game…”,” “ensuring my
child is fit medically for play/training”, and “watching my children play and treating them as soon as they are injured in any way”. Parents also saw they had a responsibility to facilitate their child’s skill development through “teaching correct tackling technique”, “ensuring my child has the necessary skills for play/training”, “discussing how best to avoid injury through better technique/skill”, and “ensuring he [my child] knows where to place his head to reduce the likelihood of concussion.” ‘Creating awareness/educating my child about concussion’ was only mentioned by two respondents as a parent’s responsibility in preventing concussion.

The prevention strategies of parents were centred on providing headgear, ensuring their child is being coached the correct playing technique, and facilitating fitness and skill development. Although educating children about concussion was only mentioned twice by parents, other parents proposed the importance of “reducing the likelihood [of concussion] through promoting safe play”; and “…installing the code of rugby, fair and clean”. There were three parents who felt that concussion could not be prevented, or were uncertain about how they could prevent it;

“Can only try to reduce the likelihood through promoting safe play…the only way to prevent concussion in rugby 100% is to not play.”

“Not sure [how to prevent concussion], headgear? Have been told this doesn’t help though.”

“No matter what you do as apparent, it is impossible to prevent a concussion entirely.”

These findings are important as parental support for sports participation is influenced by their perceptions of risk of injury to their child. In an Australian study, rugby union was found to be the second most likely sport that parents would discourage their children from playing, following rugby league (McIntosh et al., 2010). When the results were considered for boys only, 8% of parents were concerned enough to prevent participation in rugby
As a player’s intention to perform health behaviours are impacted upon by subjective norms (i.e., people are more likely to perform a behaviour if they believe important others think they should perform it; Ajzen, 1985; Godin & Kok, 1996), it is important to empower parents with effective strategies to prevent concussion in their child athletes.

First Aid/Medics. Many of the prevention responsibilities held by medics and first aiders were based around ‘risk identification’ and ‘program development and implementation’. Medics and first aiders believed one of their responsibilities in preventing concussion was to identify “at risk” players through examining player history and conducting regular screenings (e.g., axon testing, balance and symptom checks) and “prevent them from taking the field”. “Designing programs for strength and skill development”, “developing concussion plans”, and “implementing [concussion] prevention strategies” were also seen by medics and first aiders as their role-specific responsibility. Other prevention responsibilities included “educating parents, coaches, players, and officials about concussion”, “ensuring mouthguards are worn”, and “ensuring posts are padded”.

The prevention behaviours employed by medics and first aiders were varied. There was some emphasis on rule modification and facilitating appropriate coaching techniques by;

“Setting up training sessions to minimise the chance of head trauma. This can be done by restricting numbers into contact, keeping distance small so that speed of movement is less.”

“Improving physical strength and skill/coordination to minimise player being at risk.”

“Tackle technique modification, fitness training and neck strengthening”; and

“Developing a concussion plan for team including fair play/smart rugby…”
Two medics posited that their role was to conduct regular screenings to identify at risk players and educate other actors within the rugby context about concussion. Other medics/first aiders felt their role also involved enforcing protocol in multiple aspects of the game by:

“Minimising risk through ensuring appropriate coaching of technique, adherence to rules, deterring foul play, appropriate refereeing.”

“…ensuring protocol are followed.”, and

“…making sure the club, coach and team are aware of my position and role in concussion and medical management.”

The difficulties in preventing concussion in rugby were highlighted by some medics/first aiders, especially regarding ineffective headgear and poor inter-actor communication (e.g., clubs vs parents regarding safe return to play following a concussion). From these responses it may be suggested that medics/first aiders have a strong mediating role in the prevention of sport-related concussion.

**Referees.** Prevention responsibilities were consistent among all three referee respondents. Each referee stated that their roles in preventing concussion involved “running a safe game”, “enforcing the laws of the game”, and “following the Smart Rugby practices”. How they actually prevented concussion reflected this; in that referees saw it was their role to “make sure that any dangerous play is stopped immediately to prevent any injuries”, “facilitate safe play”, and “follow guidelines about safe play from Smart Rugby and referee authorities”.

**Management and Administration.** There was minimal consensus among club managers and administrative support staff on what the responsibilities were in preventing concussion. Responses included ‘facilitating communication between all actors’, ‘minimising risk where possible’, and ‘education’. Two administrators identified that
“accidental contact with the head will occur”, and “concussion cannot be prevented in contact sport, but it can be minimised”. It was stated that minimisation could be achieved through education and technique correction, however it was not clear whether this was their opinion or a role-specific behaviour they actually employed. The single respondent who held a management position stated that they would use regular screening to prevent concussion.

**Rugby-Specific Roles and Responsibilities in Identifying Concussion**

Over 93% of respondents ($n = 110$) indicated that they were able to identify the symptoms of concussion; comprised of 41% players ($n = 45$), 15.5% of both parents and first aid/medics ($n = 17$ each), 14.5% coaches ($n = 16$), 4.5% of both referees and administrators ($n = 5$ each), 2.7% volunteers ($n = 3$), and 1.8% club management ($n = 2$).

**Coaches.** Almost all of the coaches (94%) stated that they were able to identify the symptoms of concussion. The majority of coaches felt their main responsibility in the identification of concussion was to recognise a concussed player ($n = 6$; 35%), remove them from play ($n = 9$; 53%), and refer them to a medical professional ($n = 12$; 71%). It was noted by four coach respondents that they had a responsibility to remove a player from the field on the suspicion of a concussion, rather than a confirmed injury. Doctors were the most commonly named referrals ($n = 4$), followed by club paramedics (“medics”; $n = 3$) and first aiders ($n = 2$); three coaches simply cited “appropriate treatment” or general medical advice. Coaches were able to identify an average of 3.47 symptoms ($SD = 2.1$; $max = 9$). Coaches were most frequently able to identify concussion by symptoms such as ‘headache’, ‘dizziness’, ‘loss of balance’, ‘loss of memory’, ‘poor concentration’, and ‘confusion/disorientation’.

**Players.** Players’ felt their most important responsibility in identifying concussion was to check on their teammates ($n = 16$; 35.6% of players). This involved “seeing if a teammate was injured after a tackle”, “looking out for other players to ensure they are in
good health”, “letting an injured teammate know he shouldn’t keep playing”, and “just watching out for my mates”. Respondents who identified as being responsible for identifying concussion in their teammates, also noted their responsibility to then report the injury to the medic, coach, or trainer. For example;

“Identifying teammates with a concussion and informing medical staff.”

“Ensure that if a team mate has concussion, the medic, coach, trainer etc. are alerted to it.”

“If I see a fellow player concussed I will notify someone.”

In comparison, only seven respondents (16%) asserted that they were responsible for identifying concussion for themselves (e.g., “Admit to myself I have a concussion”; “Responsible for myself primarily”). Being honest and reporting a concussive injury to the coach, referee, or another official was the second most common theme identified in players’ perceived responsibilities ($n = 13; 28.9%$);

“Getting the captain's, coaches’, or ref’s attention to bring the situation to light so that proper action can be taken.”

“To let my coach and physio know how bad I feel.”

“Notify the coaches.”

“Be aware and report to management.”

Over 20% of players ($n = 10; 22%$) said their responsibility was to seek medical advice if they suspected that themselves or their teammates had a concussion. “Being honest about how you feel” was a theme presented several times in regards to reporting an injury to either an official or medical staff;

“Let the physio or doctor know that I have had a head knock.”

“Relaying to medical staff if I think I have concussion.”

“Being able to communicate to medical staff about what is going on honestly.”
Players also saw they had a responsibility to recognise the symptoms of concussion in all players on the field;

“As a player, realising symptoms in myself as well as identifying them in other players on both teams.”

“Identifying the possibility of my own teammates and another players on the field getting a blow to the head on the field during game play.”

Respondents who felt responsible for identifying concussion in their teammates, often felt additionally responsible for removing the injured player from play. Furthermore, two respondents stated they would also offer basic first aid;

“Support the player, recovery position, wait for medical help.”

“Making sure player does not rush to their feet which may lead to further injury.”

Almost one quarter of the players (n = 11; 24%) who indicated they could identify concussion did not believe they had a responsibility to do so during training or gameplay, typically seeing it as the role of the medical staff. However, almost all of these respondents still felt they had a responsibility to “look out for mates”;

“Nil [responsibility] as a player. But I will always alert the ref or medical staff if I see a teammate down on the ground.”

“None, maybe help my team mate.”

“More for the physio but if a team member has been hit on the head, I will check if they know what's going on.”

“As a player it is simply to keep an eye on my mates that have been diagnosed with concussion by a medical professional.”

When asked how they would identify concussion, players were able to list an average of 3.3 symptoms (SD = 1.99; max = 9). Players most frequently reported being able to
identify concussion by the symptoms of ‘loss of balance or clumsiness’, ‘dizziness’, ‘confusion/disorientation’, ‘nausea/vomiting’, ‘loss of memory’, ‘loss of consciousness’, and ‘blurred vision’. Players also frequently recognised changes in cognition, emotion, or behaviour (e.g., “acting off” and “suddenly playing differently”) as a sign that they or their teammates may have sustained a concussion. Several players \((n = 7; 15\%)\) proposed witnessing a head impact or ‘head knock’ as being an indication that a player may have concussion. Interestingly, no players felt they required the advice/assistance of a medic to be able to identify concussion.

**Parents.** The most consistent theme presented in what parents thought their responsibility was in identifying concussion was in regards to seeking medical help or advice from either a medic or doctor \((n = 7; 41\%)\). Some parents noted that they felt a responsibility to assist any injured player; “does not matter who the child is, I would offer an opinion and first aid until medic or QAS [ambulance] arrival”; “support child, call first aid personnel”; “keep child awake, seek medical attention.” Other parents saw their responsibility was for the wellbeing of their own child \((n = 4; 24\%)\).

“As a parent, we do our best to make sure our child is safe. He wears a headgear and mouthguard, gets transport to and from the game so we can observe any change in his behaviour. We are the last defence in making sure he's ok and hasn't suffered from concussion and may require medical supervision.”

Other themes in parents’ perceived identification responsibilities were to remove their child from play \((n = 2; 12\%)\) and to “observe and carry out medical advice” \((n = 3; 18\%)\). Two parents who were able to identify a concussion, indicated that they did not have a responsibility to do so within their role.
Parents were able to identify a mean of 2.94 concussion symptoms ($SD = 1.96$; $max = 6$). Nausea and vomiting were the most commonly identified symptoms of concussion ($n = 9$; 53% of parents), followed by ‘confusion/disorientation’ ($n = 7$; 41%). Seven parents (41%) noted that they were able to identify concussion by “seeing the incident”, “observing a head knock”, or “identifying the incident that resulted in a concussion”. ‘Loss of consciousness’, ‘memory loss’, and ‘loss of balance’ were also frequently mentioned as indicative concussion symptoms ($n = 6$ each; 35%), as were ‘persistent headaches’ and ‘dizziness’ ($n = 5$ each; 29%). Parents noted changes in cognition and behaviour more frequently than coaches and players did (23.5% compared to 18.8% and 13.3%, respectively).

**First aid/Medics.** There was almost a unanimous trend in the responses from first aid and medical support staff regarding their role in identifying concussion. Almost all respondents saw themselves as being responsible for on and off field decision making, medical assessment, and return to play. Most medics stated they had overlapping responsibilities to ‘identify a concussion’ ($n = 5$; 29%), ‘remove the injured player from the field’ ($n = 9$; 53%), ‘provide primary care’ ($n = 7$; 41%), ‘refer them for follow up medical assessment’ (e.g., doctor, hospital; $n = 6$; 35%), and ‘monitor safe return to play’ ($n = 5$; 29%).

“I am responsible for identifying a player has a concussion and removing them from play and ensuring they don't have a secondary neck injury accompanying. Immediate management and referral to the correct person (i.e., hospital if bad). Assessing the graded return to play.”

“Get the player off [the field], assess, and direct to doctors if needed. Ensure safe return to play after cleared by doctors.”

“Recognise and diagnose a concussion and ensure no return to play. Educate on graduated return to play.”
“It is my responsibility to remove any player who I suspect to have a concussion or who is developing the signs of one and provide medical assessments and refer to appropriate medical facilities.”

Three medics (18%) stated that their responsibilities included utilising formal measures (e.g., Sport Concussion Assessment Tool [SCAT2]) to identify concussion, although one respondent mentioned this would only be done at Super Rugby or National levels. Interestingly, it was common for medics to quote the slogans from the Australian Rugby Union (2014) and International Rugby Board (2014) concussion guidelines; such as “If in doubt, sit them out”, and “Recognise and Remove”. Four medics (24%) also saw they had a responsibility to “communicate with key staff and educate players, families, partners etc. about concussion”.

First aid/medics were able to identify an average of 4.18 symptoms (SD = 2.24; max = 10). Over 70% (n = 12) of these respondents said they would use formal guidelines and/or measures to identify concussion. The Sideline Concussion Assessment Tool (SCAT2; McCrory et al, 2013) was the most frequently specified measure (n = 6; 35%), followed by Maddocks’ questions (Maddocks, Dicker, & Saling, 1995) and the IRB Concussion Recognition Tool (CRT; IRB, 2014) which were both named four times (24% each). Five respondents (26%) reported they would identify concussion by using general field side tests, including assessments of motor control (e.g., balance/coordination) and cognitive recall/memory. Identifying symptoms that were most commonly recognised by first aid/medics included ‘loss of memory and balance’, ‘nausea/vomiting’, ‘headache’, ‘loss of consciousness’, and ‘changed behaviour and cognition’. Nearly 30% (n = 5) of first aid respondents also noted that “mechanism of injury” or “observation of head knock” was key to identifying a concussion, along with 3 respondents (18%) who emphasised the importance of player observation and history assessment.
**Referees.** Four out of five referees (80%) stated their biggest responsibility was to remove concussed athletes from play, however only two respondents saw it was their responsibility to identify a concussion. One referee stated that although they are not always confident about identifying concussion, they would still insist that an injured player leave the field to be assessed by medical staff. Three of the respondents (60%) also felt they had a responsibility to ensure an injured player sought first aid. Referees were able to identify a mean of 2.67 symptoms ($SD = 2.73$, $max = 8$). Confusion and disorientation were the most frequent symptoms identified by referees ($n = 5$). Loss of balance ($n = 3$) and loss of consciousness ($n = 2$) were the only other identifying symptoms named by this group.

**Management and Administration.** Half of the sample of administrators and club management respondents indicated that although they could identify a concussion, they do not have a responsibility to do so within their roles. The other administrators felt they had a responsibility to have “properly trained personnel” and “provide education”. The second club manager’s responsibility was to “escalate the injury to medical practitioner, and seek clearance before allowing to participate in rugby activities (on and off the field).” Participants who identified as being either a club manager or administrator, identified an average of 2.71 symptoms of concussion ($SD = 1.5$, $max = 5$). When asked how they do or would identify a concussion, administrators suggested that they would assess the nature of the collision and look for changes in the characteristics and behaviours of the players. Specific symptoms identified were ‘loss of consciousness’, ‘loss of balance’, and ‘slurred/slow speech’. One administrator stated that they identified concussion by “watching, assessing, and prior knowledge and experience.” Club management noted that they would also watch for a “knock to the head”, however would also seek a doctor’s assessment. Both management respondents identified ‘headaches’ and ‘nausea/vomiting’ as symptoms of
concussion, as well as ‘disorientation’, ‘memory loss’, ‘loss of motor function’, and ‘seizures’.

Volunteers. All of the volunteers in the study \((n = 3)\) indicated that they were able to identify a concussion. Their perceived responsibilities included “handling concussion carefully”, “involving the club doctor”, and “making decisions on field as to whether or not concussion has occurred.” Volunteers reported being able to identify a mean of 3.33 symptoms of concussion \((SD = 2.3, max = 6)\). ‘Disorientation’ was noted as an identifying symptom of concussion by all volunteers. Volunteers also stated they identified concussion by the “mechanism of injury”, “when a player lies on the ground and can’t move”, “unconsciousness”, and “neurological signs (e.g., memory recall, coordination, emotional state, and headaches).”

Concussion Treatment Roles and Responsibilities within the Rugby System

Thirty-two respondents \((29\%)\) indicated that, within their role, they were involved in treating concussion. This sample was mostly made up of first aid/medics \((n = 15; 47\%)\), which represented 88% of all of the medics in the study. The rest of the sample was comprised of 19% parents \((n = 6)\), 15.6% players \((n = 5)\), 12.5% coaches \((n = 4)\), and one volunteer. None of the club managers, administrators, or referees identified as being involved in treating concussion within their roles.

First aid/Medics. Eighty-eight percent of first aid respondents stated that they had a role in treating concussion. The main responsibilities in concussion treatment held by medics were to provide primary care and immediate injury assessment. This was done by utilising concussion assessment tools (e.g., SCAT2 and online tests), as well as “treatment of neck/headaches, balance, and vision…”; “monitoring symptoms, timing the length of unconsciousness”; and “providing on field medical assessment.” Supervising gradual/safe return to play was another common theme presented by first aiders, with over half \((n = 8;\)
53%) of respondents highlighting this as their responsibility within their role. Specifically, medics felt they had a responsibility to “ensure [injured players] have the adequate time off for recovery before returning to training”; and “graduated return to school and play”. Other responsibilities included immediately removing injured players from the field ($n = 3; 18\%$), and referring them for follow up medical assessment ($n = 3; 18\%$). When asked how they would treat concussion, 53% of first/aid medic respondents stated that they would treat a concussion with “rest until symptom free”;

- “Physical and cognitive rest followed by progressive loading over at least 6 days so long as completely symptom free in accordance with Zurich guidelines.”
- “Advise mental and physical rest.”
- “Rest and graduated return to play guided by symptoms.”
- “Rest until symptom free, then graduate training according to symptoms.”
- “Rest until symptom-free. Age-appropriate GRTP.”

Additional treatment strategies included referring injured players for further medical assessment/medical clearance ($n = 6$), removing the injured player from play ($n = 5$; furthermore ensuring they “never return to the field that day”), and providing first aid assessment ($n = 6$).

- “It depends on the severity of the incident. If player is unconscious then I would treat that injury as a neck injury. If player is conscious but disoriented, I would still try and keep the player still...”
- “Stabilising the neck when a player is unconscious to rule out a secondary neck injury that are associated with head knocks.”

Parents. One third of parents in this study identified as having a role in treating concussion. Mostly parents’ responsibilities in concussion treatment involved monitoring
their child’s health/symptoms ($n = 3$), and ensuring their child received appropriate medical attention ($n = 3$). One parent also highlighted their responsibility to “do what the doctor or medical staff say”. Four out of six parents (67%) said they would treat a concussion by seeking medical advice from a doctor or taking their child to hospital (one of these respondents had medical training, and stated that she would take her child to definitive care after first providing comprehensive first aid). The other two parents said they would treat their child’s concussion with rest;

“Child to rest, avoid sleeping initially, monitor every hour, check coordination and the level of consciousness.”

“Rest and a mild analgesic. Medical assessment only if required.”

**Players.** Only 1% of players in the study indicated they had a role in treating concussion ($n = 5$; 4 of whom were female). Treatment responsibilities held by players included “listening and adhering to medical advice”, “helping out where I can as directed by medical staff, “being responsible for my own wellbeing and the wellbeing of others”, and “getting adequate rest and taking the concussion test.” One player stated that they did not have any responsibilities in treating concussion. The two common themes in *how* players treated concussion were ‘seeking medical attention’ (and adhering to it; $n = 3$), and ‘rest’ (which was specified as, “no thinking, no visual stimulus, and using a hyperbaric chamber”; and “no alcohol”).

**Coaches.** Two of the four coaches who identified as having a role in treating concussion stated that their responsibility was to “ensure players receive medical treatment”/“call a doctor”. The other coaches specified their responsibility was to provide basic first aid, check for symptoms of concussion, and “keep them [the injured] calm and awake.” The treatment strategies employed by coaches were to keep the patient calm and
responsive while medical attention was being sought, “use the SCAT”, and “ensure an appropriate recovery period.”

**Volunteers.** The volunteer who proposed their role in treating concussion, stated their responsibility was to “report back to coaching staff regarding the signs/symptoms [of an injured player], and player education.” “Rest” was the treatment strategy suggested by the volunteer, which was in line with the rest of the sample. Specifically, “reduce screen time, minimise contact in training, advise time off school” was suggested.

**Transfer of Knowledge**

When asked where respondents believed their overall knowledge on sport-related concussion had come from, the majority of the sample (60%) indicated that their knowledge had come from a medical professional; other frequent responses were ‘general knowledge’ (38%), ‘coach’ (29%), and ‘research/formal guidelines’ (26%; see Table 14). Players, coaches, and parents most commonly identified ‘medical professional’ (58%, 81%, and 47%, respectively), followed by ‘general knowledge’ (42%, 44%, and 53%, respectively) as their primary sources of concussion-related knowledge. Demonstrating a hierarchical flow of information, players frequently noted ‘coaches’ (44%) as a primary source of information; while coaches noted their ‘club/organisation’ (56%). Club management identified ‘medical professional’ (50%) as a primary source of information, and medics most commonly gained their knowledge from ‘research/formal guidelines’ (82%).
Table 14. “Overall where do you think your knowledge on concussion has come from?”

<table>
<thead>
<tr>
<th>Knowledge source</th>
<th>Player (n = 43)</th>
<th>Coach (n = 16)</th>
<th>Parent (n = 17)</th>
<th>Management (n = 2)</th>
<th>Medic (n = 17)</th>
<th>Admin (n = 5)</th>
<th>Volunteer (n = 2)</th>
<th>Referee (n = 5)</th>
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Note. * Percentage of % of n. **Respondents were instructed to indicate all options which applied to them.
Discussion and Recommendations

The aim of the research project was to utilise a systems perspective to explore how people within different roles prevent, identify, and treat sport-related concussion in community rugby union. A better understanding of the attitudes and actions pertaining to sport-related concussion prevention, treatment, and management is important as sport participation is influenced by perceptions of injury risk. For example, irrespective of the well-known benefits of team sport participation, an Australian study showed that, consequent of concerns regarding concussion risk, rugby union was the second most likely sport that parents would discourage their children from playing (4%), following rugby league (13%; Boufous, Finch, & Bauman, 2007). Therefore, the present study employed a systems analysis of qualitative responses from key stakeholders (i.e., players, coaches, parents, medics, volunteers, referees, management, and administration), to assess the gaps and overlaps in role-specific responsibilities and strategies regarding the prevention, identification, and treatment of rugby-related concussion.

It is important to note that it is not the intention for the authors to make any conclusions regarding the way forward in concussion management. This study was the first to apply a systems perspective to better understanding the way concussion is currently prevented, identified, and treated. As such, it is recommended that the findings of this study be seen as a baseline for future investigations to work against. It also illustrated the clear applicability of systems thinking concussion management and therefore may be useful in future research to assess intervention strategies and guideline efficacy. Despite this, this study did reveal several important findings within each domain of concussion management.

Perceived Prevention Responsibilities in Rugby-Related Concussion

There were strong similarities in the coach and player perspectives of their roles in preventing rugby-related concussion. Proper training, technique correction, and education
were recurrent themes reported by both player and coach respondents; which was further reinforced by parent respondents. This synchronicity may be explained by the frequency of multiple roles shared between these levels of the community rugby system. For example, in this study, 25% of coaches held a secondary role as either a player or parent. Similarly, one in 10 players also occupied a secondary role as a coach or parent. The biggest discrepancy in the shared responsibilities between these actors was in the specificity of their responses. That is, compared to coaches, players’ perceptions of their responsibilities tended to be less definitive; while parents’ responses had a stronger support perspective, compared to the coaches who described more generative responsibilities. The most consistent role-specific responsibilities presented in this study were reported by medics and referees, which were centered on creating a safe environment and enforcing concussion management protocol, respectively.

Targeted training, with a focus on correct tackling technique and avoiding head contact, was a recurring theme within the prevention strategies proposed by all actors within the community rugby system. This finding suggests that the majority of community rugby participants recognise that lack of technique, practice, and awareness regarding typical gameplay contact (e.g., tackling) is associated with the greater risk of sustaining a concussion (Cusimano, Nassiri, & Chang, 2010; Gardner et al., 2014; Hollis et al., 2009). Although use of protective gear (i.e., headgear and mouthguards) was a concussion prevention strategy presented by 36% of parents and utilised by over 40% of players (supporting Baker et al., 2013), several actors from different levels of the rugby system asserted that this was not effective in preventing concussion. Furthermore, there were respondents within each level of the system who considered concussion as an inevitable aspect of rugby participation, which can only be mediated not prevented completely. This may reflect either an acceptance of the physical nature of contact football, or a lack of confidence in the efficacy of the current...
concussion management guidelines. More research should be conducted to better understand this system-wide concern.

The strategies presented by club managers and referees were reflective of their positions (i.e., managers managed the multiple levels of the community rugby system; referees enforced the laws of the game); conversely, there was notable variance in the prevention strategies adopted by medical aides. The strategies presented by first aid and medical support staff were often multi-faceted, considering many aspects of concussive injury. Medics were the most likely respondents within the rugby system to specify protocol from formal guidelines (e.g., “Recognise and Remove” from IRB, 2014). This finding suggests that education programs targeted at community first aid and medical support staff are been understood and implemented to some degree in this level of the system. However the effective implementation of the CIS guidelines within other roles is still questionable, as no other responding group reported these strategies specifically (i.e., by name).

**Contextual Concerns for Identification of Rugby-Related Concussion**

The systems analysis of this data illustrated that the majority of the key stakeholders in the rugby system were consistently able to identify concussion, and saw it as their role-specific responsibility to do so. Respondents within each level of the system were able to identify an average of two to five symptoms of concussion, which is roughly 10% of the total number of symptoms presented in the CIS consensus guidelines (McCrory et al., 2013). Although this finding suggests that despite the differential definitions proposed in literature regarding the definition of concussion, participants at all levels of participation are able to recognise some of the salient indicators of concussive injury (e.g., loss of balance, memory, and/or consciousness), there still appears to be a large knowledge deficit. Medics and first aid personnel were the only members of the system who saw it as their responsibility to utilise standardised concussion assessment measures (e.g., SCAT2) to identify concussion.
However this was only identified by 18% of the medical respondents, with one medic stating that these measures would only be used in the professional leagues. This may be due to the absence of medical support staff available at junior and amateur training and games (Borich et al., 2013; Cohen et al., 2009; Makdissi et al., 2013). Standardised measures, such as the SCAT2, require an athlete’s pre-injury functioning to be recorded; as such, unless they are used consistently, these measures are somewhat ineffective in identifying an individual’s concussion-related changes in functioning. For this discrepancy to be addressed, it would be worthwhile to gain a systems perspective of why standardised measures are not being used at all levels of competition, and how future measures may be developed to address these issues to improve their implementation.

A positive finding from this study was the strong sense of mateship presented by many of the rugby players, who saw it as their responsibility to identify concussion in their teammates and other players. This finding highlights some important considerations for the interpersonal level of the SE system (Green & Kreuter, 1999), in regards to possible reporting behaviours and the impact of social desirability. In rugby underreporting is often motivated by players not thinking concussion was a serious injury, and/or not wanting to be withheld from participation (Hollis et al., 2012; Gardner et al., 2014). The hyper-masculine subculture often present in contact football has been associated with creating environments of increased injury risk, consequent of the shared ethos of “putting the team first” and “giving 110%” (Tibbert, Andersen, & Morris, 2015). While this may encourage some players to feel they have to ‘play through the pain’ and downplay their injuries; the responses in the present study demonstrated that players feel responsible for “looking out for [their] mates”, even more so than themselves. This finding has significant implications for possible future interventions to improve the dissemination of sport-related concussion awareness. Some of the noted challenges in identifying concussion (e.g., underreporting, delayed diagnoses) may be
ameliorated by developing targeted knowledge transfer strategies which advocate the role of mateship in identifying concussion (e.g., “friends don’t let friends play while concussed”) and promote a cultural shift which normalises the recognition and unbiased reporting of concussive injuries.

Another significant trend identified in present study, was that actors within each level of the rugby system regularly referred to the IRB (2014) concussion awareness and management strategies (i.e., the ‘6Rs’); specifically the majority of respondents saw it as their responsibility to recognise the symptoms of concussion, remove the injured from play, and refer them for medical assessment. Conversely, there was a concerning portion of respondents across all levels of the system who indicated that despite being able to identify a concussion, they did not see it as their specific responsibility to do so within their role. For example, nearly one quarter of rugby players stated that they could identify a concussion, however saw it as the role of the medical staff to diagnose and manage concussive injury. Almost all medics stated their role in being responsible for on and off field decision making concerning injury assessment and return to play guidance. Furthermore, nearly one quarter of the medical aid respondents felt they had a responsibility to facilitate communication as well as provide concussion education across all levels of the rugby system. Although medical personnel are often the most impartial actors within the system who are qualified to make decisions regarding concussion management (Clacy, Sharman, & Lovell, 2013b), the multiplicity of their roles and inconsistent presence in junior and amateur sport (Borich et al., 2013; Makdissi et al., 2013) creates a potential gap in concussion identification and management.

Given the reliance on medical staff to diagnose concussion from every level of the rugby system (including management, administration, and referees), strategies should be implemented at the organisational level to ensure that properly trained medical personnel are
both (a) available at all rugby training and game events, irrespective of competition grade; and (b) consistently utilise standardised assessment tools to record every athlete's baseline functioning as well as to assess and diagnose concussion as soon as possible (i.e., field-side). Alternatively, identification responsibilities may need to be formally delegated more evenly across the rugby system. For example, assigning the task of collecting regular baseline measures of functioning to club administrators; and encouraging parents to adopt a more active role in educating their children on the seriousness of concussion recognition and management.

**Treatment Discrepancies in Rugby-Related Concussion**

Less than one third (29%) of the respondents in this study indicated that they were involved in treating concussion within their role, however there were consistent similarities in the responses that were offered. Medical personnel were the most frequent respondents who acknowledged their role-specific responsibilities in treating concussion; with their responses consistently reflecting the concussion management guidelines proposed by the IRB (2014) and ARU (2014). The common treatment themes presented by first aid and medical personnel reflected the IRB’s 6Rs (i.e., recognise, remove, refer, rest, recover, return). Although there were other levels of the rugby system involved in treating concussion (specifically, parents, coaches, and players); the most common themes presented by these actors were ‘refer the injured for further medical assessment’ and ‘adequate rest’ (i.e., two of the six management guidelines). None of the respondents offered a specific amount of rest time that they would prescribe to a concussed athlete, rather it was proposed that the injured should be monitored until symptom free. This could be due to either a gap in knowledge or a recognition for the significance of promoting an individually ‘tailored’ graded return to play progression rather than a ‘one size fits all’ approach (Finch et al., 2013).
It is concerning that only 1% of actors within the ‘player’ level of the rugby system indicated their role in treating sport-related concussion; in concurrence with only 25% of parents and coaches. As per the Theory of Reasoned Action, the weakness in this aspect of concussion management could have considerable implication on reporting and return to play behaviour (Ajzen, 1985; Godin & Kok, 1996). That is, if actors in closest proximity to concussion do not hold any intention or perceived responsibilities in treating concussion, this may likely precede an absence of reasoned or planned action in the event of injury. Previous research has demonstrated that inconsistencies in concussion treatment knowledge and advice may impact the implementation of- and compliance with graded return to play protocol (Finch et al., 2013; Hollis et al., 2012). For example, Hollis et al. (2012) found that 78% of rugby players who sustained or suspected a concussion failed to receive return-to-play advice; and those who did receive the correct advice failed to comply with regulations. The findings of the present study therefore provide further support the need for a system-wide revision to address this gap in the role-specific responsibilities of different actors in treating concussion, with consideration for the specific ecological structure and context of community rugby.

Through the application of a systems perspective, a striking discontinuity of concussion management information between first aid and medical staff and the coaches, players, and parents in the rugby environment was identified. The hierarchical flow of information observed in the knowledge transfer responses from all actors may offer some insight into where the communication of current concussion education and management strategies are being disrupted. These concerns about ineffective concussion management guideline dissemination have been identified in previous research (Donaldson & Finch, 2011; Finch et al., 2013; Poulos & Donaldson, 2014; White et al., 2013). Although there was a limited number of respondents within the management and administration levels of the rugby
system in the present study, the paucity in these responses highlights an additional discordance in the dissemination of concussion management protocol. Improving the consistency and implementation of effective prevention and treatment of concussive injury will benefit participants across all levels of rugby participation. Ongoing, negative media focus on the long-term effects of concussion should not deter people from participating in rugby and other forms of contact sport, where the positive health benefits of participation are considerable. Rather, it should serve as a stimulus for a cultural change in the system-wide attitudes toward concussion and its management.

**Limitations**

As the first study of its kind, there are a number of limitations that require noting. Firstly, there was a limited distribution of actors across the system; namely, there was an absence of participants from the upper levels of the system (e.g., Australian Rugby Union spokespersons, sports medicine professionals; professional athletes etc.). The similarities and differences in concussion management responsibilities and strategies identified in this study may not be a representative of the entire rugby union sample. Although the focus of this study was on community and amateur sport rather than professional levels of competition, with consideration for Rasmussen’s risk management framework and systems thinking, future research should assess concussion management across the entire system to ensure the perceptions and actions of all rugby actors are appropriately considered. Similarly, a second limitation of this study was the sample size, specifically the unequal distribution of actors within different roles (e.g., 50 players compared to 2 club managers). Future research should aim to recruit equal numbers of participants within each level of the rugby system to ensure each group is accurately represented in the data. Equipment and environmental factors should also be considered in more detail.
Chapter Seven – Overall Discussion and Final Conclusion

The ABCS of Concussion

The overall goal of this project was to determine whether the antecedents, behaviours, and consequences of paediatric and adolescent sport-related concussion could be predicted through the concurrent analysis of individual intrinsic and extrinsic biopsychosocial variables; while also considering the concussion management beliefs and behaviours throughout the whole rugby system. The main emphasis of this investigation was to provide some objective clarification to existing research, which has produced largely contradictory results. Identifying how the antecedents, behaviours, consequences, and sociocultural factors interact to predict an athletes’ risk of sustaining a concussion was proposed as an essential step in advancing how sport-related concussion is prevented, identified, and treated in rugby union. A combined descriptive and sociotechnical systems approach was taken to address these goals, consisting of both quantitative self- and parent-report data, as well as qualitative open-ended response data. This allowed for a systematic analysis of biopsychosocial variables to be conducted efficiently, while also providing an opportunity to get a differential perspective of how concussion is managed within the multiple levels of the rugby union community. The final chapter in this thesis summarises the main findings of this project, and discusses the possible implications for how this information may be used to advance how sport-related concussion is prevented, identified, and managed in community rugby.

The Antecedents

At the outset of the project, a comprehensive review was conducted to synthesize the current literature regarding both the vulnerability of adolescents to mild traumatic brain injuries, such as concussion, as well as the varied hypotheses regarding the aetiology of sport-related concussion. From a developmental perspective, adolescence poses a sensitive period in development, consequent of the progressive hormonal, neurological, and psychosocial
changes that typically occur during this stage. This has considerable implications when exploring the risk factors to concussion in sport, as rapid changes in cognitive ability and social motivation have been found to exacerbate the identification and reporting challenges frequently faced in sport-related concussion management. As such, the first study in this project took a biopsychosocial approach to examining the antecedents to sport-related concussion in junior rugby union, with specific focus on the intrinsic variables which may impact an individual’s risk of injury. It was hypothesised that the concussion incidence may be modulated by a range of intrinsic factors, thus the concurrent analysis of these factors could be used to profile ‘at risk’ athletes. Informed by previous research, the intrinsic biopsychosocial variables examined were athletes’ age, physical composition (i.e., BMI), aerobic fitness, prenatal testosterone exposure (as measured by digit span ratio), impulsivity, executive function, premorbid psychopathology, and sociological influences.

Although the results of this study failed to significantly identify a profile of an ‘at risk’ athlete, some noteworthy trends emerged that may have valuable implications for future concussion management strategies. The considerable physical differences (i.e., BMI and aerobic fitness) between early- and late- adolescents, for example, offered a possible explanation for the interaction between an athlete’s age and their risk of concussion. The average BMI of the participants in this study increased from 19.6 to 23 between 11 to 13 year old athletes and 14 to 17 year old athletes, respectively; this represents a difference of 19 centimetres and 22 kilograms. On one side of the ‘age as a risk factor’ debate, research has suggested that the greater game speed, fitness levels, and player size and strength associated with more mature players may increase their risk of injury (Gessel et al., 2007; Hollis et al., 2009; Makdissi et al., 2013). Conversely, the inverse has also been found between heightened concussion risk in younger athletes due to lower fitness, body mass, and musculature (Cohen et al., 2009; Guskiewicz et al., 2004; Hasler, Carmont, & England,
With consideration for the rapid physical growth that occurs throughout adolescence, sport-related concussion risk in this age group may be heightened by the interaction of both of these assertions, given the substantial disparity in physical composition within just a few years of age. This was further illustrated in this study by the substantial disparity in physical composition within the pre-adolescent and adolescent age groups. Pre-adolescents (11 to 13 years) reported deviations in height and weight of 11 centimeters and 10.5 kilograms; while 14 to 17 year old adolescents reported deviation of up to 7.0 centimeters and 15.6 kilograms. This is not the first time these physical disparities have been brought to attention when considering injury risk management.

The International Rugby Board currently promotes player pathways based on age bandings (i.e., Age Grade Rugby), however there has been growing interest in introducing weight restrictions into junior sport (IRB, 2015). At present, weight cut-off criteria has only been implemented in junior rugby in New Zealand and India, although has been used for some time in other contact sports, such as boxing and American Football. The IRB (2015) state that there is more to consider than just young athletes’ physical development, as participation is also dependent on an athlete’s competence and skill development, team identification, and competitive readiness. While these are factual considerations, the traditional method of grading junior rugby by age alone does not appear to take into consideration the rapidly declining age of pubertal onset. Moving forward, it is recommended that the physical characteristics of young athletes should be taken into stronger consideration in future concussion management strategies in junior rugby.

**The Behaviours**

Although not directly predictive of sport-related concussion, an athlete’s intrinsic biopsychosocial characteristics do influence how they react to the situation-specific extrinsic factors which may facilitate the manifestation of injury (e.g., training behaviours, sporting
culture, equipment use; Wiese-Bjornstal, 2010). The way a young athlete interacts with their environment is further influenced by characteristic developmental changes which occur during adolescence, such as cognitive improvement (e.g., problem solving skills, strategic behaviour), changing social motivation, and egocentrism with subsequent impulsivity and risk taking behaviour. This formed the basis of the second hypothesis of this project; that is, that an athlete’s playing position, training practices, use of protective wear (or lack thereof), and risk taking behaviours would present as extrinsic risk factors to concussion in junior athletes. The extrinsic variables that were found to most impact the likelihood of sustaining a concussion were training related behaviours, specifically time spent training unsupervised and use of protective gear when training. In conjunction with the negative correlation between athlete age and use of headgear and/or mouthguards; the finding that adolescent athletes who trained unsupervised for 5 or more hours per week, either alone or with a friend, were nearly six times more likely to sustain a concussion is illustrative of the previously noted decline in sport-related health protecting behaviours throughout adolescence (Finch, Donohue, & Garnham, 2002; McIntosh et al., 2009).

Despite adolescent athletes typically having more developed risk-assessment abilities compared to younger athletes, it is proposed that the pseudo-cultural masculine pressure for rugby players to ‘play tough’ may encourage young athletes to play more recklessly when training unsupervised, especially when training with their peers (Kerr et al., 2014; Wiese-Bjornstal, 2010). Conversely, this study also found evidence for a health promoting function of adolescent team sport participation, specifically in regards to cigarette and alcohol consumption. None of the athletes in this study smoked cigarettes, and only 10% of 14 to 17 year old participants consumed alcohol regularly, which is substantially lower than the national average of 86.2% for this age group (AIHW, 2014). This finding provides support for a social learning perspective on alcohol use in adolescent team sport, in that young
athletes may be less likely to use alcohol if their teammates are also non-alcohol users (Vest & Simpkins, 2013). Together these findings illustrate a possible cultural impact on risk taking behaviours in junior rugby union, which could have significant implications on future concussion-related interventions in adolescent sport. That is, psychosocial characteristics may be a pertinent consideration to proactively altering how young athletes react in sport-specific situations (e.g., unsupervised training, use of protective gear, return-to-play) by creating a cultural shift towards more health promoting behaviours surrounding concussion management.

The Consequences

A further significant contribution of this study was in regards to the recovery profile and possible long-term consequences of concussion on cognitive and emotional functioning in young athletes. Consistent with previous research (e.g., Belanger & Vanderploeg, 2005; Broglio & Puetz, 2008; McCrory et al., 2013), the majority of adolescent athletes who had sustained a medically diagnosed concussion had recovered from their injury within 10 days, including 61% who believed they had recovered within 24 hours. The contribution of this finding is substantial, as this study controlled for self-report bias by implementing rigorous case selection criteria which only included medically diagnosed concussions and cases with convergent parent- and self-report data. This finding however, should not undermine the importance of a gradual return-to-play schedule as the specific mechanisms underpinning post-concussive recovery are still not well understood, especially concerning the development of secondary symptoms and post-concussion syndrome. With this in mind, the reported 40% of participants who indicated that they returned to play on the same day of their injury is an issue that requires addressing. The ARU (2014) and IRB (2014) both advocate for a three week break from participating in both training and competition following a head injury causing concussion; however this finding, in conjunction with previous research (e.g.,
Chrisman et al., 2012; Hollis et al., 2012), suggests that this is either not being enforced or is not being complied with in community rugby union. With physical and cognitive rest being proposed by the international consensus on sport-related concussion as the cornerstone of neurocognitive recovery (McCrory et al., 2013), this divergence in concussion management should be a priority for future interventions.

Despite the vexing return to play behaviours reported by participants in this study, there were still no consequences to cognitive or emotional functioning identified in participants’ who had sustained neither a single nor multiple concussions. Although this analysis was limited by a cross-sectional design and a small proportion of participants who had sustained multiple concussions, the absence of any significant disruptions to academic performance, executive functioning, or emotional regulation following a concussive injury adds support to an existing body of research (Bruce & Echemendia, 2009; Collie, Iverson et al., 2006; Collie, McCrory, & Makdissi, 2006). This is not to say that concussive injury in child and adolescent athletes is not an urgent issue; rather this assertion should reiterate the necessity for individualised injury assessments which should be based on regular baseline testing to account for confounding factors which may be impacting upon injury recovery and cognitive performance in a fast developing population. More comprehensive prospective research is required to better understand the cumulative effects of concussive injury as it pertains to neuropsychological recovery, attenuation in cognitive performance, and potential influences on long-term functioning.

The Sociotechnical System Interactions

As highlighted by the findings of the earlier studies in this project, factors associated with sport-related injury risk are comprised of both the interaction of intrinsic biological characteristics, as well as the actions of the athlete with the extrinsic physical and sociocultural characteristics and events within the sport-specific context. Given that an
individual’s beliefs and behaviours are a function of their interaction with their immediate, social, and organisational environments (Provvidenza et al., 2013), a systems approach was employed to gain a broader perspective of how concussion is managed within the multiple levels of the rugby union community. The main aim of this analysis was to identify between- and within- role discrepancies in the perceived responsibilities and applied strategies pertaining to three domains of concussion management (i.e., prevention, identification, and treatment). It was hypothesised that by taking a system-wide perspective on the attitudes and actions of key stakeholders towards concussion management, role-specific themes could be identified with consideration for the specific ecological structure and context of community rugby. The novel adaptation of this framework to the multiple levels of the rugby system revealed both commonalities and inconsistencies in each domain of management.

Between-role discrepancies in the perceived efficacy of prevention strategies were a recurrent theme identified in this analysis. Proper training, technique correction, and education were recurring themes within the prevention strategies proposed by all actors within the community rugby system; conversely, there were also respondents within each level of the system who considered concussion as an inevitable aspect of rugby participation, which can only be mediated not prevented completely. This pattern may be reflective of a context supported acceptance of the physical nature of contact football, or a lack of confidence in the efficacy of the current concussion management guidelines. Attitudes towards a behaviour predict the likelihood of that behaviour being implemented and maintained (Ajzen, 1985), thus this finding may offer some explanation for the discrepancies and issues observed in the operational efficacy of the current intervention strategies in community rugby (e.g., Collins, Fields, & Comstock, 2008; Hollis et al., 2012). Future injury prevention interventions need to consider how concussion prevention and management guidelines are disseminated within a rugby specific context, and how the relevance and value
of the information is perceived and communicated between the roles in each level of the system (Finch et al., 2013). This should be considered in conjunction with the earlier proposition that psychosocial factors are a pertinent consideration to creating a behavioural shift towards more health promoting behaviours in a sporting context. Specifically, role-specific relevant information is more likely to be translated throughout the system through social learning if it is perceived as valuable by everyone within the context, therefore a rugby specific system-wide approach to the translation of future prevention interventions would facilitate context-sensitive implementation.

The sideline identification of concussion is consistently noted in literature as being the most challenging aspect of sport-related concussion management, arising out of inconsistencies in sideline protocol, such as use of screening tools and unclear role responsibilities (Cohen et al., 2009; McKeever & Schatz, 2003). This was illustrated in this study by between- and within-role discrepancies in perceived identification responsibilities. Although participants at all levels of the system were able to recognise some of the salient indicators of concussive injury (e.g., loss of balance, memory, and/or consciousness), there was a system-wide reliance on medical staff to diagnose concussion. With consideration for the community rugby context, this finding offers new insight into how several of the context-specific challenges identified in junior rugby union may interact and complicate concussion management. Firstly, the infrastructure of amateur sport often relies on volunteer or trainee medical staff, consequently medics are not always present at both training and game events. This is irregularity may then impede the consistent use of standardised identification measures both for recording baseline functioning as well as for field-side assessment and diagnosis (indeed only 18% of the medics in this study used these measures). Efficient identification and accurate diagnosis of concussion may then be complicated by the absence of standardised methods, which would have a flow on effect to the enforcement of justified
removal from play and subsequent gradual return to play recommendations. To the author’s knowledge, this is the first time this interaction has been systematically identified in research. Developing strategies to ameliorate this discrepancy in the rugby system may have substantial implication to the efficacy and successful implementation of future concussion management guidelines.

This system-wide reliance on medical personnel to manage rugby-related concussion was seen to extend further into perceived treatment responsibilities, as illustrated by only 1% of athletes and only a quarter of both parent and coach respondents indicating their role-specific responsibilities in treating sport-related concussion. When considered together, these system-wide trends offer insight into the specific junctures within the rugby system which may be dislocating the effective communication, internalisation, implementation, and enforcement of effective concussion management. Together the findings of this study should be seen as a baseline for future investigations to work against. This study clearly demonstrated the applicability of systems thinking to better understanding system-wide concussion management beliefs and behaviours. This perspective it would therefore be useful to apply to future research which aim to assess management strategies and information dissemination campaigns.

**Advancing Across the Advantage Line**

This project offered a comprehensive analysis of the antecedents, behaviours, and consequences associated with concussion risk in junior rugby union, with theoretically informed consideration for intrinsic biopsychosocial factors as well as individual extrinsic factors. Furthermore the novel adaptation of the sociotechnical systems approach to a rugby-specific context provided insight to the broader contextual and ecological factors that influence how concussion is managed within the multiple levels of the rugby union community. The concurrent analysis of a theory driven selection of biological,
psychological, and psychosocial variables in this project addressed many of the limitations presented in previous research, including inconsistencies in injury definitions, non-generalisable samples, and uncontrolled confounding factors. The individual findings of this study each have notable and extensive applications to advancing how sport-related concussion is understood and managed, and were used throughout this thesis to inform several recommendations for future guideline revisions. To try and draw an overarching conclusion from this project would be negligent to the multifaceted nature of sport-related concussion.

The primary goal of this project was to determine whether concussion risk could be predicted in junior athletes based on their individual characteristics, instead what was found was the variation in concussion risk was largely unpredictable, illustrating the dynamic nature of sport-related concussion risk in junior rugby. Despite this study being cross-sectional (thus causality cannot be inferred), to advance how sport-related concussion is understood in children and adolescents, individual differences and modifiable extrinsic factors should only be considered within the context in which they occur. Sociocultural influence was a consistent theme throughout each of the four studies within this project, suggesting that the existing pseudo-cultural beliefs may be guiding the attitudes, behaviours, and beliefs that young rugby players have regarding concussion. As such, a cultural shift in contact sports to encompass a better understanding of- and acceptance for ‘invisible injuries’ such as concussion should be facilitated by the whole system. This would have a flow on effect to identification issues through the minimisation of reporting bias, and wider implementation of regular screening; and more unanimity in how concussion is treated, as it would be more accepted and understood by the wider community.

This project was motivated to identify the rugby-specific factors and contextual interactions which may be used to better inform the advancement of how sport-related
concussion is prevented, identified, and treated in junior community sport. The unique learning environment offered through team sport participation during childhood and adolescence facilitates the formation of identity and a range of cultural knowledge and social skills not present in any other context. Ongoing, negative media focus on the long-term effects of concussion should not deter people from participating in rugby and other forms of contact sport, where the positive health benefits of participation are considerable. Instead, sport-related concussion should be considered in the full context of benefits of sports participation, and serve as a stimulus for a cultural change in the system-wide attitudes toward concussion and its management. The impact of this kind of cultural shift is beginning to emerge as participation in a team sport presents more of a health-promoting function in adolescents, and the strong sense of mateship consistently exhibited by rugby players in this study demonstrates well developed social skills and prosocial reasoning. Sport-related concussion may be an inevitable part of rugby participation, and there are still many questions that require clarification, especially in regards to the long-term implications of concussive injuries. Future research should aim to improve concussion knowledge and management while still considering the ‘bigger picture’ by informing the development of balanced prevention and concussion management strategies without losing sight of the many developmental benefits for children and adolescents which are unique to the team sport environment.
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APPENDIX 1. ABC of Concussion Questionnaire (Child Version)

ATHLETE TO COMPLETE

11 to 13 years

**Player Information**

1. First name: ____________________  Last name: ____________________
2. Age _______  Date of birth: ___/___/______
3. What year/grade are you in at school? ____________________
4. Most of the time, what marks/grades do/did you usually get for your work?
   - [ ] Mostly A’s  [ ] Mostly B’s  [ ] Mostly C’s  [ ] Mostly D’s
5. How long have you played Rugby Union for? _____months _____years
6. Which team do you mainly play for at the moment?
   ________________________________________
7. Do you play for any other teams (e.g., rep teams)? [ ] Yes  [ ] No
   a) If **YES**, which other team/s do you play for?
   ________________________________________
8. Do you play any other sports?  [ ] Yes  [ ] No
   a) If **YES**, what kind? ________________________________________
9. In **Rugby**, what position do you **usually** play? (please tick **ONE** box only)
   - [ ] Hooker  [ ] Prop  [ ] Lock  [ ] Flanker  [ ] Number eight
   - [ ] Halfback  [ ] Five eighth  [ ] Centre  [ ] Wing  [ ] Fullback
10. How many **hours** each **week** do you spend training
   a. With your rugby team?
      - [ ] None  [ ] Less than 1hr  [ ] 1 – 2hrs  [ ] 3-4hrs  [ ] More than 5hrs
   b. By yourself/just with friends?
      - [ ] None  [ ] Less than 1hr  [ ] 1 – 2hrs  [ ] 3-4hrs  [ ] More than 5hrs
11. Do you wear **protective headgear** when you play rugby?

During training: □ Always □ Often □ Sometimes □ Rarely □ Never

During a game: □ Always □ Often □ Sometimes □ Rarely □ Never

11. Do you wear a **mouth guard** when you play rugby?

During training: □ Always □ Often □ Sometimes □ Rarely □ Never

During a game: □ Always □ Often □ Sometimes □ Rarely □ Never

Concussion may be caused either by a knock to the head, face, neck or body injuring the brain. Not everyone feels the same after a concussion, but some people may get a bad headache or feel dizzy, sick, ‘foggy’, or unbalanced.

12. Have you **ever** had a concussion either playing Rugby or doing anything else? □ Yes □ No

a) If NO, please go to Page 4. If YES, please answer the following:

i. Who diagnosed this concussion?

□ Team medic □ Family doctor (GP) □ Physiotherapist

□ Other (please specify) __________________________________________

ii. How many times have you **ever** had concussion? _______________

iii. How many times have you had a concussion in the past 12 months?

_________________

iv. When was the last time you had a concussion? ___________________

v. Was this an injury you got while playing **Rugby**? □ Yes □ No

If NO, how were you injured?

________________________________________
b) When you last got a concussion did you experience any of the following? Please tick all that apply.

- □ Headache
- □ Nausea (feeling sick)
- □ Loss of memory
- □ Dizziness
- □ Vomiting
- □ Poor concentration
- □ Blurred vision
- □ Numbness/tingling in arms/legs
- □ Disorientation/feeling ‘foggy’
- □ Sensitivity to light
- □ Loss of balance
- □ Depression/irritability
- □ Sensitivity to sound
- □ Loss of consciousness
- □ Trouble getting to sleep/insomnia
- □ Nervousness
- □ Drowsiness/fatigue
- □ Aggressiveness


c) Did you go and see a doctor? □ Yes □ No

a. If YES, who?

- □ Team medic
- □ Family doctor (GP)
- □ Physiotherapist
- □ Other (please specify) ________________________________


d) After your last concussion, how long did it take for you to recover?

- □ Less than 24 hours
- □ 1-3 days
- □ 4-7 days
- □ 8-10 days
- □ 11-14 days
- □ More than 2 weeks


d) Did you stop playing Rugby and training while you recovered? □ Yes □ No

- • If YES, how long was it until you returned to training/play?

- □ Returned the same day of injury
- □ Within 7 days
- □ Within 1-2 weeks
- □ Within 2-3 weeks
- □ Did not return to play for the rest of the season


e) Following your concussion did you start using headgear?

- □ Yes  □ No  □ Already wore it
People are different in the ways they act and think in different situations. For the next section, read each statement and tick the box for how well each statement describes you. Do not spend too much time on any statement, answer quickly and honestly.

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<td>□</td>
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<tr>
<td>I usually share with others (for example toys and food).</td>
<td>□</td>
<td>□</td>
<td>□</td>
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<td>I get very angry and often lose my temper.</td>
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<td>□</td>
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<td>I have one good friend or more.</td>
<td>□</td>
<td>□</td>
<td>□</td>
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<tr>
<td>I fight a lot. I can make other people do what I want.</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>I am often unhappy, depressed or tearful.</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>Other people my age generally like me.</td>
<td>□</td>
<td>□</td>
<td>□</td>
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<tr>
<td>I am easily distracted. I find it difficult to concentrate.</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>I am nervous in new situations. I easily lose confidence.</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>I am kind to younger children.</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>I am often accused of lying or cheating.</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>Other children or young people pick on me or bully me.</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>I often volunteer to help others (parents, teachers, other children).</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>I think before I do things.</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>I take things that are not mine from home, school or elsewhere.</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>I get along better with adults than with people my own age.</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>I have many fears, I am easily scared.</td>
<td>□</td>
<td>□</td>
<td>□</td>
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</table>
I finish the work I am doing. My attention is good. □ □ □ □

Please put a circle around the word that shows how often each of these things happen to you. There are no right or wrong answers.

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<tr>
<td>1.</td>
<td>I worry about things.</td>
<td>Never</td>
<td>Sometimes</td>
</tr>
<tr>
<td>2.</td>
<td>I feel sad or empty.</td>
<td>Never</td>
<td>Sometimes</td>
</tr>
<tr>
<td>3.</td>
<td>When I have a problem, I get a funny feeling in my stomach.</td>
<td>Never</td>
<td>Sometimes</td>
</tr>
<tr>
<td>4.</td>
<td>I worry when I think I have done poorly at something.</td>
<td>Never</td>
<td>Sometimes</td>
</tr>
<tr>
<td>5.</td>
<td>I would feel afraid of being on my own at home.</td>
<td>Never</td>
<td>Sometimes</td>
</tr>
<tr>
<td>6.</td>
<td>Nothing is much fun anymore.</td>
<td>Never</td>
<td>Sometimes</td>
</tr>
<tr>
<td>7.</td>
<td>I feel scared when I have to take a test.</td>
<td>Never</td>
<td>Sometimes</td>
</tr>
<tr>
<td>8.</td>
<td>I feel worried when I think someone is angry with me.</td>
<td>Never</td>
<td>Sometimes</td>
</tr>
<tr>
<td>9.</td>
<td>I worry about being away from my parents.</td>
<td>Never</td>
<td>Sometimes</td>
</tr>
<tr>
<td>10.</td>
<td>I get bothered by bad or silly thoughts or pictures in my mind.</td>
<td>Never</td>
<td>Sometimes</td>
</tr>
<tr>
<td>11.</td>
<td>I have trouble sleeping.</td>
<td>Never</td>
<td>Sometimes</td>
</tr>
<tr>
<td>12.</td>
<td>I worry that I will do badly at my school work.</td>
<td>Never</td>
<td>Sometimes</td>
</tr>
<tr>
<td>13.</td>
<td>I worry that something awful will happen to someone in my family.</td>
<td>Never</td>
<td>Sometimes</td>
</tr>
<tr>
<td>14.</td>
<td>I suddenly feel as if I can’t breathe when there is no reason for this.</td>
<td>Never</td>
<td>Sometimes</td>
</tr>
<tr>
<td>15.</td>
<td>I have problems with my appetite.</td>
<td>Never</td>
<td>Sometimes</td>
</tr>
<tr>
<td>16.</td>
<td>I have to keep checking that I have done things right (like the switch is off, or the door is locked).</td>
<td>Never</td>
<td>Sometimes</td>
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<tr>
<td>17.</td>
<td>I feel scared if I have to sleep on my own.</td>
<td>Never</td>
<td>Sometimes</td>
</tr>
<tr>
<td>18.</td>
<td>I have trouble going to school in the mornings because I feel nervous or afraid.</td>
<td>Never</td>
<td>Sometimes</td>
</tr>
<tr>
<td>19.</td>
<td>I have no energy for things.</td>
<td>Never</td>
<td>Sometimes</td>
</tr>
<tr>
<td>20.</td>
<td>I worry I might look foolish.</td>
<td>Never</td>
<td>Sometimes</td>
</tr>
<tr>
<td>21.</td>
<td>I am tired a lot.</td>
<td>Never</td>
<td>Sometimes</td>
</tr>
<tr>
<td>22.</td>
<td>I worry that bad things will happen to me.</td>
<td>Never</td>
<td>Sometimes</td>
</tr>
<tr>
<td>23.</td>
<td>I can’t seem to get bad or silly thoughts out of my head.</td>
<td>Never</td>
<td>Sometimes</td>
</tr>
<tr>
<td>24.</td>
<td>When I have a problem, my heart beats really fast.</td>
<td>Never</td>
<td>Sometimes</td>
</tr>
<tr>
<td>25.</td>
<td>I cannot think clearly.</td>
<td>Never</td>
<td>Sometimes</td>
</tr>
<tr>
<td>26.</td>
<td>I suddenly start to tremble or shake when there is no reason for this.</td>
<td>Never</td>
<td>Sometimes</td>
</tr>
<tr>
<td>27.</td>
<td>I worry that something bad will happen to me.</td>
<td>Never</td>
<td>Sometimes</td>
</tr>
<tr>
<td>28.</td>
<td>When I have a problem, I feel shaky.</td>
<td>Never</td>
<td>Sometimes</td>
</tr>
<tr>
<td>29.</td>
<td>I feel worthless.</td>
<td>Never</td>
<td>Sometimes</td>
</tr>
<tr>
<td>30.</td>
<td>I worry about making mistakes.</td>
<td>Never</td>
<td>Sometimes</td>
</tr>
<tr>
<td>31.</td>
<td>I have to think special thoughts (like numbers or words) to stop bad things from happening.</td>
<td>Never</td>
<td>Sometimes</td>
</tr>
<tr>
<td>32.</td>
<td>I worry what other people think of me.</td>
<td>Never</td>
<td>Sometimes</td>
</tr>
<tr>
<td>33.</td>
<td>I am afraid of being in crowded places (like shopping centres, the movies, buses, busy playgrounds).</td>
<td>Never</td>
<td>Sometimes</td>
</tr>
<tr>
<td>34.</td>
<td>All of a sudden I feel really scared for no reason at all.</td>
<td>Never</td>
<td>Sometimes</td>
</tr>
<tr>
<td>35.</td>
<td>I worry about what is going to happen.</td>
<td>Never</td>
<td>Sometimes</td>
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</tr>
<tr>
<td>36. I suddenly become dizzy or faint when there is no reason for this.</td>
<td>Never</td>
<td>Sometimes</td>
<td>Often</td>
</tr>
<tr>
<td>37. I think about death.</td>
<td>Never</td>
<td>Sometimes</td>
<td>Often</td>
</tr>
<tr>
<td>38. I feel afraid if I have to talk in front of my class.</td>
<td>Never</td>
<td>Sometimes</td>
<td>Often</td>
</tr>
<tr>
<td>39. My heart suddenly starts to beat too quickly for no reason.</td>
<td>Never</td>
<td>Sometimes</td>
<td>Often</td>
</tr>
<tr>
<td>40. I feel like I don’t want to move.</td>
<td>Never</td>
<td>Sometimes</td>
<td>Often</td>
</tr>
<tr>
<td>41. I worry that I will suddenly get a scared feeling when there is nothing to be afraid of.</td>
<td>Never</td>
<td>Sometimes</td>
<td>Often</td>
</tr>
<tr>
<td>42. I have to do some things over and over again (like washing my hands, or putting things in a certain order).</td>
<td>Never</td>
<td>Sometimes</td>
<td>Often</td>
</tr>
<tr>
<td>43. I feel afraid that I will make a fool of myself in front of people.</td>
<td>Never</td>
<td>Sometimes</td>
<td>Often</td>
</tr>
<tr>
<td>44. I have to do some things in just the right way to stop bad things from happening.</td>
<td>Never</td>
<td>Sometimes</td>
<td>Often</td>
</tr>
<tr>
<td>45. I worry when I go to bed at night.</td>
<td>Never</td>
<td>Sometimes</td>
<td>Often</td>
</tr>
<tr>
<td>46. I would feel scared if I had to stay away from home over night.</td>
<td>Never</td>
<td>Sometimes</td>
<td>Often</td>
</tr>
<tr>
<td>47. I feel restless.</td>
<td>Never</td>
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Thank you for your time 😊
APPENDIX 2. ABC of Concussion Questionnaire (Adolescent Version)

**ATHLETE TO COMPLETE**

**14 to 17 years**

**Player Information**

13. First name: _______________  Last name: _______________

14. Age _______  Date of birth: ___/___/______

15. Telephone number: Home (____)_____________Mobile ________________

16. What is the highest level of schooling you have undertaken so far?

☐ Year 8  ☐ Year 9  ☐ Year 10  ☐ Year 11  ☐ Year 12  ☐ TAFE/Trade

17. Most of the time, what marks/grades do/did you usually get for your school work?

☐ Mostly A’s  ☐ Mostly B’s  ☐ Mostly C’s  ☐ Mostly D’s

18. How often do you drink alcohol?

☐ Never  ☐ Very Rarely  ☐ Monthly  ☐ Weekly  ☐ Daily

19. If/when you do drink alcohol roughly how many drinks do you have?

☐ 1-2 drinks  ☐ 3-4 drinks  ☐ 5-6 drinks  ☐ 7-8 drinks  ☐ 10+ drinks

20. How often do you smoke cigarettes?

☐ Never  ☐ Very Rarely  ☐ Monthly  ☐ Weekly  ☐ Daily

21. How long have you played Rugby Union for? _______months _______years

22. Which team do you currently play for?

______________________________________________

23. Do you play for any other teams (e.g., rep teams)? ☐ Yes  ☐ No

a) If **YES**, which other team/s do you play for?

______________________________________________

24. Do you play any other sports? ☐ Yes  ☐ No

a) If **YES**, what kind? ___________________________________
25. In Rugby, what position do you usually play? (please tick ONE box only)

- Hooker
- Prop
- Lock
- Flanker
- Number eight
- Halfback
- Five eighth
- Centre
- Wing
- Fullback

26. How many hours each week do you spend training

   a. With your Rugby team?

- None
- Less than 1hr
- 1 - 2hrs
- 3 - 4hrs
- More than 5hrs

   b. By yourself/ just with friends?

- None
- Less than 1hr
- 1 - 2hrs
- 3 - 4hrs
- More than 5hrs

27. Do you wear protective headgear when you play rugby?

   During training:  
   - Always
   - Often
   - Sometimes
   - Rarely
   - Never

   During a game:  
   - Always
   - Often
   - Sometimes
   - Rarely
   - Never

28. Do you wear a mouth guard when you play rugby?

   During training:  
   - Always
   - Often
   - Sometimes
   - Rarely
   - Never

   During a game:  
   - Always
   - Often
   - Sometimes
   - Rarely
   - Never

Concussion may be caused either by a knock to the head, face, neck or body injuring the brain. Not everyone feels the same after a concussion, but some people may get a bad headache or feel dizzy, sick, ‘foggy’, or unbalanced.

29. Have you ever had a concussion?  
   - Yes
   - No

   a) If NO, please go to Page 4. If YES, please answer the following:

   i. Who diagnosed this concussion?

- Team medic
- Family doctor (GP)
- Physiotherapist

- Other (please specify) ____________________________

   ii. How many times have you ever had concussion? __________

   iii. How many times have you had a concussion in the past 12 months? __________

   iv. When was the last time you had a concussion? __________

   v. Was this an injury you got while playing Rugby?  
   - Yes
   - No
If **NO**, how were you injured? ___________________________________ 

b) When you **last** got a concussion did you experience any of the following? **Please tick all that apply.**

- □ Headache  
- □ Nausea (feeling sick)  
- □ Loss of memory  
- □ Dizziness  
- □ Vomiting  
- □ Poor concentration  
- □ Blurred vision  
- □ Numbness/tingling in arms/legs  
- □ Disorientation/feeling ‘foggy’  
- □ Sensitivity to light  
- □ Loss of balance  
- □ Depression/irritability  
- □ Sensitivity to sound  
- □ Loss of consciousness  
- □ Trouble getting to sleep/insomnia  
- □ Nervousness  
- □ Drowsiness/fatigue  
- □ Aggressiveness  

c) Did you seek professional medical attention? □ Yes □ No  

  a. If **YES**, who?  
- □ Team medic  
- □ Family doctor (GP)  
- □ Physiotherapist  
- □ Other (please specify) ____________________________________ 

d) After your **last** concussion, how long did it take for you to recover?  

- □ Less than 24 **hours**  
- □ 1-3 **days**  
- □ 4-7 **days**  
- □ 8-10 **days**  
- □ 11-14 **days**  
- □ More than 2 **weeks**  

e) Did you stop playing/training Rugby while you recovered? □ Yes □ No  

  - If **YES**, how long was it until you returned to training/play?  

- □ Returned the same **day** of injury  
- □ Within 7 **days**  
- □ Within 1-2 **weeks**  
- □ Within 2-3 **weeks**  
- □ **Did not** return to play for the rest of the season  

f) Following your concussion did you start using headgear?  

- □ Yes  
- □ No  
- □ Already wore it
People are different in the ways they act and think in different situations. For the next section, read each statement and tick the box for how well each statement describes you. Do not spend too much time on any statement, answer quickly and honestly.

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<td>I act on the spur of the moment.</td>
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For the next section, please tick the box for how well each statement describes you (either ‘Not True’, ‘Somewhat True’ or ‘Certainly True’). It would help us if you answered all of the questions as best you can, even if you aren’t sure. Please give us your answers for how you have felt in over the last six months.

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<th>Somewhat True</th>
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<td>I am restless. I cannot stay still for long.</td>
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<td>I get a lot of headaches, stomach-aches or sickness.</td>
<td></td>
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<td>I usually share with others.</td>
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<td>I get very angry and often lose my temper.</td>
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<td>I usually do as I am told.</td>
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<td>I am helpful if someone is hurt, upset or feeling ill.</td>
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<tr>
<td>I have one good friend or more.</td>
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<td>I fight a lot. I can make other people do what I want.</td>
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<td>I am often unhappy, depressed or tearful.</td>
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<td>Other people my age generally like me.</td>
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<td>I am easily distracted. I find it difficult to concentrate.</td>
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<td>I am nervous in new situations. I easily lose confidence.</td>
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<tr>
<td>I am kind to younger children.</td>
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<td>I am often accused of lying or cheating.</td>
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<tr>
<td>Other children or young people pick on me or bully me.</td>
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<tr>
<td>I often volunteer to help others (parents, teachers, children).</td>
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<tr>
<td>I think before I do things.</td>
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<tr>
<td>I take things that are not mine from home, school or elsewhere.</td>
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<tr>
<td>I get along better with adults than with people my own age.</td>
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<tr>
<td>I have many fears, I am easily scared.</td>
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<tr>
<td>I finish the work I am doing. My attention is good.</td>
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</table>
Please put a circle around the word that shows how often each of these things happen to you. There are no right or wrong answers.

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<th></th>
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<th>Never</th>
<th>Sometimes</th>
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<tr>
<td>48.</td>
<td>I worry about things.</td>
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<td>49.</td>
<td>I feel sad or empty.</td>
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<td>50.</td>
<td>When I have a problem, I get a funny feeling in my stomach.</td>
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<td>51.</td>
<td>I worry when I think I have done poorly at something.</td>
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<td>52.</td>
<td>I would feel afraid of being on my own at home.</td>
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<td>53.</td>
<td>Nothing is much fun anymore.</td>
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<td>54.</td>
<td>I feel scared when I have to take a test.</td>
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<td>55.</td>
<td>I feel worried when I think someone is angry with me.</td>
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<td>56.</td>
<td>I worry about being away from my parents.</td>
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<td>57.</td>
<td>I get bothered by bad or silly thoughts or pictures in my mind.</td>
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<td>58.</td>
<td>I have trouble sleeping.</td>
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<td>59.</td>
<td>I worry that I will do badly at my school work.</td>
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<td>60.</td>
<td>I worry that something awful will happen to someone in my family.</td>
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<td>61.</td>
<td>I suddenly feel as if I can’t breathe when there is no reason for this.</td>
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<td>62.</td>
<td>I have problems with my appetite.</td>
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<td>63.</td>
<td>I have to keep checking that I have done things right (like the switch is off, or the door is locked).</td>
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<td>64.</td>
<td>I feel scared if I have to sleep on my own.</td>
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<td>65.</td>
<td>I have trouble going to school in the mornings because I feel nervous or afraid.</td>
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<td>66.</td>
<td>I have no energy for things.</td>
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<td>67.</td>
<td>I worry I might look foolish.</td>
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<td>68.</td>
<td>I am tired a lot.</td>
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<td>69.</td>
<td>I worry that bad things will happen to me.</td>
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<td>70.</td>
<td>I can’t seem to get bad or silly thoughts out of my head.</td>
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<td>71.</td>
<td>When I have a problem, my heart beats really fast.</td>
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<td>72.</td>
<td>I cannot think clearly.</td>
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<td>73.</td>
<td>I suddenly start to tremble or shake when there is no reason for this.</td>
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<td>74.</td>
<td>I worry that something bad will happen to me.</td>
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<td>75.</td>
<td>When I have a problem, I feel shaky.</td>
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<td>76.</td>
<td>I feel worthless.</td>
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<td>77.</td>
<td>I worry about making mistakes.</td>
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<td>78.</td>
<td>I have to think special thoughts (like numbers or words) to stop bad things from happening.</td>
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<td>79.</td>
<td>I worry what other people think of me.</td>
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<td>80.</td>
<td>I am afraid of being in crowded places (like shopping centres, the movies, buses, busy playgrounds).</td>
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<td>81.</td>
<td>All of a sudden I feel really scared for no reason at all.</td>
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<td>82.</td>
<td>I worry about what is going to happen.</td>
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<td>83.</td>
<td>I suddenly become dizzy or faint when there is no reason for this.</td>
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<td>84.</td>
<td>I think about death.</td>
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<td>85.</td>
<td>I feel afraid if I have to talk in front of my class.</td>
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<td>86.</td>
<td>My heart suddenly starts to beat too quickly for no reason.</td>
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<td>87.</td>
<td>I feel like I don’t want to move.</td>
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<td>88. I worry that I will suddenly get a scared feeling when there is nothing to be afraid of.</td>
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<td>89. I have to do some things over and over again (like washing my hands, or putting things in a certain order).</td>
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<td>90. I feel afraid that I will make a fool of myself in front of people.</td>
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<td>91. I have to do some things in just the right way to stop bad things from happening.</td>
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<td>92. I worry when I go to bed at night.</td>
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<td>93. I would feel scared if I had to stay away from home over night.</td>
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<td>94. I feel restless.</td>
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</table>

Thank you for your time 😊
APPENDIX 3. ABC of Concussion Questionnaire (Parent Version)

Information Sheet - Adolescents
“Antecedents, Behaviours, and Consequences
Associated with Concussion in Junior Rugby Union”

Chief Investigator - Amanda Clacy, B.Soc.Sci. (Psych.)(Hons.) USC.
Phone +614 3110 7329 or email aclacy@usc.edu.au

Research Supervisor – Dr. Rachael Sharman, PhD Qld.UT, B.Psych(Hons) Qld.UT, BA Qld.
Phone (07) 5456 5073 or email rsharman@usc.edu.au

Research Supervisor – Dr. Geoff Lovell, PhD Manc.Met, BSc(Hons) St Mary's College UK.
Phone (07) 5456 5100 or email glovell@usc.edu.au

Introduction
Team sport participation encourages community interaction as well as providing the chance for fundamental aspects of development for children and adolescents, including acquisition of motor skills, improved physical fitness, opportunities to learn life skills (e.g., discipline, leadership, and self-control), and psychosocial development (e.g., peer interaction, co-operation, mateship).

However, the risk of injury in contact sports is impossible to prevent completely. Concussion may be caused either by a knock to the head, face, neck or body injuring the brain. Not everyone feels the same after a concussion, but some people may get a bad headache or feel dizzy, sick, ‘foggy’, or unbalanced. Our research team is especially interested in why some athletes who play contact sports, such as Rugby Union (Rugby), are more likely to sustain a concussion than others. The present study aims to evaluate specific individual characteristics (such as age, executive function, impulsive behaviours, level of aerobic fitness) associated with sustaining a head injury, leading to concussion. The research team asks for your participation in investigating these possible risk factors to concussion in children and adolescents who play Rugby.

Why we chose you
One of the biggest questions in research on sport-related concussion is ‘why do some athletes bounce, while others break?’ This is especially an issue in child and adolescent age groups (8 to 17 years) as there are considerable neurological, cognitive, and hormonal changes occurring during these ages. Although short-term disruption to these functions can be seen in the more immediate symptomology of concussion (e.g., impaired memory, mood disturbance), the individual characteristics during this period of development which place some athletes more at risk of - or
alternatively appear to protect from - sustaining a head injury in sport and experiencing ongoing symptoms of concussion is not well understood. With your help, this study aims to improve understanding of these issues and advance awareness of the effect of concussion on an athlete’s development.

**Method and participation**

The proposed research aims to gather information using both a self-report and parent-report questionnaire, as well as some non-invasive physical measures. Athletes will be asked to fill out a questionnaire asking about topics such as demographics, previous concussions, impulsivity/sensation seeking, prosocial behaviour, depression and anxiety, and use of helmets and headgear. This should take no more than 30 minutes to complete. Digital scans of each of the athlete’s hands will also be taken to determine their prenatal testosterone exposure and their height and weight will be recorded to calculate their body mass index (BMI). Finally each athlete’s level of fitness (maximum oxygen uptake or VO2 max) will be assessed using the ‘Beep’ test, which is a multi-stage 20 meter shuttle run test for aerobic fitness which can last up to approximately 25 minutes. All of this information will be gathered from the athletes during their regularly scheduled Rugby practice sessions. Parents and guardians of the athletes will also be asked to participate in this study by completing a short demographic questionnaire and an assessment of executive function regarding their child in their own time. A reply paid envelope will be provided to each participant’s family for the simple return of the completed questionnaires to the research team.

**Risks**

Physical fitness tests, such as the Beep Test, have a negligible degree of physical risk (participants may trip/fall/become out of breath). Administration of this test will be supervised by either the PhD candidate or the coach to minimise any chance of injury. Furthermore, administration of the Revised Children’s Anxiety and Depression Scale (RCADS) questionnaire may lead some participants to be mildly psychologically distressed as questions assess depression and anxiety symptomology. The RCADS is a validated and standardised across clinical and non-clinical paediatric populations thus the chance of psychological risk is negligible however in the instance that athletes indicate thoughts of self-harm or suicide, this information will be passed onto the USC Psychology Clinic and the parent/guardian of the individual will be contacted. Counselling services are available through the Child and Youth Mental Health Services (CYHMS) on 07 3310 9444 or the child’s general practitioner.
Expected benefits
The results of this study will potentially influence the return-to-play guidelines for contact sport, thereby reducing the incongruence currently experienced in the medical attention given to injured athletes. Participants will benefit from more informed, individually adapted treatment and assessment of concussion and subsequent return-to-play guidelines. By gaining understanding of what makes some players more at risk of adverse and ongoing symptoms of concussion, athletes’ injuries will be assessed individually and comprehensively. Furthermore, this study will have beneficial implications for the wider community as it will hopefully provide evidence for the questions that surround children’s participation in contact sports, such as Rugby.

Voluntary participation
Participation in this study is entirely voluntary for both athletes and parents/guardians. If you do agree to participate, you can withdraw from the project at any time during the study without any comment or penalty. Your decision to participate or not to participate, will in no way affect your current relationship with your coach or Rugby club, or with the University of the Sunshine Coast. No incentive/payback or reimbursement is being offered to participants for participation.

Confidentiality
All responses and data will be treated with strict confidentiality. Individual information and responses will only be made available to members of the research team, as listed at the head of this document. Questionnaire and physical data will be stored in a password protected computer file; all paper copies of consent forms and original questionnaire results will be stored in a locked filing cabinet in the office of Dr. Rachael Sharman onsite at USC for the minimum prescribed 5 year period following any publication or conference paper reporting on the project. Research data may be accessed by auditors, ethics committees, or regulatory authorities. If the data is accessed it will not include any names. Data from this study may also be published however no published material will contain participant names or identifiable information.

Disclosure of funding sources
This project has applied for financial support from the University of the Sunshine Coast.

Feedback
Data will be analysed as a group, as such individual data will not be available however participants may have access to the study’s main findings by contacting the research team. This research project is the subject of Miss Clacy's PhD candidature; as such a 'by publication' thesis will be produced (i.e., articles will be published in both peer reviewed journals as well as in a final dissertation, however all participant information will be anonymous and unidentifiable). A plain language summary of results can also be provided by the research team upon request, refer to the top of this document for contact details.

**Further information**
This study also forms the basis of a longitudinal investigation which will be conducted by Dr Rachael Sharman and Dr Geoff Lovell, by which changes in participant’s test scores will be re-assessed every 12 months over a period of 10 years. If you have any questions or require any further information about the present project or the subsequent longitudinal research, please do not hesitate to contact the research team. Please see the heading of this document for a full list of contact information.

**Concerns or complaints**
The Human Research Ethics Committee of the University of the Sunshine Coast has approved this study. If you have any complaints about the way this research project is being conducted you can raise them with the Principal Researcher. If you prefer an independent person, contact the Chairperson of the Human Research Ethics Committee at the University: (c/- the Research Ethics Officer, Office of Research, University of the Sunshine Coast, Maroochydore DC 4558; telephone (07) 5459 4574; email humanethics@usc.edu.au).

*Both the research team and the University of the Sunshine Coast sincerely thank you for your assistance in investigating this important area.*
APPENDIX 4. ABC of Concussion Information Sheet

**PARENT/GUARDIAN TO COMPLETE**

“Antecedents, Behaviours, and Consequences
Associated with Concussion in Junior Rugby Union”

<table>
<thead>
<tr>
<th><strong>Chief Investigator</strong></th>
<th>- Amanda Clacy, B.Soc.Sci. (Psych.)(Hons.) USC.</th>
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<tr>
<td></td>
<td>Phone +614 3110 7329 or email <a href="mailto:aclacy@usc.edu.au">aclacy@usc.edu.au</a></td>
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<tr>
<td><strong>Research Supervisor</strong></td>
<td>- Dr. Rachael Sharman, PhD <em>Qld.UT</em>, B.Psych(Hons) <em>Qld.UT</em>, BA <em>Qld.</em></td>
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<td>Phone (07) 5456 5073 or email <a href="mailto:rsharman@usc.edu.au">rsharman@usc.edu.au</a></td>
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<tr>
<td><strong>Research Supervisor</strong></td>
<td>- Dr. Geoff Lovell, PhD <em>Manc.Met</em>, BSc(Hons) <em>St Mary's College UK.</em></td>
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<td></td>
<td>Phone (07) 5456 5100 or email <a href="mailto:glovell@usc.edu.au">glovell@usc.edu.au</a></td>
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**Parent Information**

30. Given name:________ _______ Family name:__________________________
31. Relationship to player: __________________________________________
32. Telephone number: Home (__)___________ Work (__) _____________
      Mobile ___________________
33. Postcode: __ __ __ __
34. Does anybody else in your immediate family play contact sport? □ Yes □ No
   a) If YES, what is their relationship to the player? __________________
   b) Which sport/s do they play? _____________________________________

**Player Information**

35. Given name:______ ____ Family name:_________ Date of birth:__/__/_____
36. How long has your child played Rugby Union? ______months _______years
37. Which team/s does your child play for?
38. Does/has your child play/ed any other sport? □ Yes □ No
   a) If YES, what kind?

39. In Rugby, what position does your child usually play? (please tick ONE box only)
   □ Hooker □ Prop □ Lock □ Flanker □ Number eight
   □ Halfback □ Five eighth □ Centre □ Wing □ Fullback

Concussion may be caused either by a knock to the head, face, neck or body injuring the brain. Not everyone feels the same after a concussion, but some people may get a bad headache or feel dizzy, sick, ‘foggy’, or unbalanced.

40. Has your child ever sustained a concussion? □ Yes □ No
   a) If YES,
      i. Who diagnosed this concussion?
         □ Team medic □ Family doctor (GP) □ Physiotherapist
         □ Other (please specify) ____________________________
      ii. How many times have they ever had a concussion? ___________
      iii. How many times have they had a concussion in the past 12 months? ___________
      iv. When was the last time they had a concussion? ___________
      v. Was this an injury they sustained while playing Rugby? □ Yes □ No

      If NO, how were they injured? ____________________________

b) When they were last concussed did they show any of the following symptoms? Please tick all that apply.
   □ Headache □ Nausea (feeling sick) □ Loss of memory
   □ Dizziness □ Vomiting □ Poor concentration
   □ Blurred vision □ Numbness/tingling in arms/legs □ Disorientation/feeling ‘foggy’
Sensitivity to light  
Loss of balance  
Depression/irritability

Sensitivity to sound  
Loss of consciousness  
Trouble getting to sleep/insomnia

Nervousness  
Drowsiness/fatigue  
Aggressiveness

c) Was formal medical attention sought?  Yes  No
   • If YES, who?
      Team medic  Family doctor (GP)  Physiotherapist
      Other (please specify) _________________________

d) After their last concussion, how long did it take for them to recover?
   更短于 24 hours  1-3 days  4-7 days
   8-10 days  11-14 days  More than 2 weeks

e) Did your child stop training/playing Rugby while they recovered?  Yes  No
   • If YES, how long was it until they returned to training/play?
      Returned the same day of injury  Within 7 days  Within 1-2 weeks
      Within 2-3 weeks  Did not return to play for the rest of the season

f) Following your child’s concussion did they start using headgear?
   Yes  No  Already wore it

41. Has your child received treatment/diagnosis from a doctor/health professional for any of the following? (tick all applicable)
   Epilepsy  Meningitis  ADHD (ADD)  Learning difficulties
   Depression  Anxiety  Migraines  Brain injury/disease
   Schizophrenia  Other (please specify) _________________________

42. Is your child currently on any prescription medication?

   a) If YES, please provide details
APPENDIX 5. Online Questionnaire: Roles and Responsibilities in Sport-Related Concussion

Responsibilities in the Identification, Prevention, and Treatment of Concussion in Rugby Union

Consent
This study has been approved by the Human Research Ethics Committee of the University of the Sunshine Coast (S/14/662). Participation in this study is voluntary and all responses are anonymous.

Are you over the age of 16? □ Yes □ No

If you are under the age of 16, please ask your parent/guardian for permission before continuing this survey.
My parent/guardian has given consent for me to participate. □ Yes □ No

I have read and understood the information sheet and consent to participate in this study. □ Yes □ No

Demographics
Date of birth __/__/____ Gender □ Male □ Female
What is the highest level of education you have completed? __________________
How long have you been involved with rugby union? _______months ________years

The following questions are about which role you most frequently identify with in rugby union. You may have only one role (e.g., you may only identify as a player), or you may have more than one role (e.g., you may identify as both a coach and a parent).

What is your primary role in rugby union? (i.e., what do you do most frequently?)

Identification
Are you able to identify concussion/ symptoms of a concussion? □ Yes □ No
If yes, how would you/ do you identify a concussion?

In your role, what are your responsibilities in identifying a concussion?

Prevention
Are you involved in preventing a concussion? □ Yes □ No
If yes, how would you/do you prevent a concussion?

In your role, what are your responsibilities in preventing a concussion?

Treatment
Are you involved with treating a concussion? □ Yes □ No
If yes, how would you/do you treat a concussion?

In your role, what are your responsibilities in treating a concussion?

Multiple Roles
Do you have any other roles in rugby union? □ Yes □ No
If yes, what is your other role in rugby union?

Would your responses to the questions regarding identification, prevention, and treatment of concussion be any different in the other roles? □ Yes □ No

Education
Overall where do you think most of your knowledge on the identification, prevention, and treatment of concussion has come from? Please tick all that apply.

□ Parents □ Team mates □ Coach □ Club/Organisation rules □ School
□ University/ TAFE □ Medical professional (e.g., doctor, physiotherapist)
□ Internet (e.g., social media, blogs) □ Media (e.g., news, sport updates)
□ General knowledge □ Research (e.g., published guidelines, medical journals)
□ Other (please specify)
APPENDIX 6. Information Sheet: Roles and Responsibilities in Sport-Related Concussion

Information Sheet

“Responsibilities in the Prevention, Identification, and Treatment of Concussion in Rugby Union: A Qualitative Investigation (S/14/662)”

Chief Investigator
Dr Rachael Sharman, PhD QUT, B.Psych(Hons) QUT, BA Qld.
Phone (07) 5456 5073 or email rsharman@usc.edu.au

Research Supervisor
Dr Geoff Lovell, PhD Manc.Met, BSc(Hons) UK
(07) 5456 5100 or email glovell@usc.edu.au

Research Supervisor
Prof Paul Salmon, PhD Brun., MSc Sund., BSc Sund.
Phone (07) 5456 5893 or email psalmon@usc.edu.au

Research Supervisor
Dr Natassia Goode, PhD Syd., BA Syd.
Phone (07) 5456 5850 or email ngoode@usc.edu.au

PhD Candidate
Amanda Clacy, B.Soc.Sci. (Psych.)(Hons.) USC.
Phone +614 3110 7329 or email aclacy@usc.edu.au

Introduction
Sport-related concussion has become a popular topic of concern in the media and in the sporting community. While there are guidelines for the identification and management of concussion, there is still a lot of confusion as to what is considered best practice and who should be responsible for implementing it. Concussion is a complex issue and there are often many people involved when a head injury occurs, including everyone from players, coaches, parents, and referees to medics/first-aiders, volunteers and club administration and management. The identification, prevention, and treatment of concussion has never been researched at a systems level (i.e., when we look at everyone involved). The study that we are seeking your participation in aims to investigate how individuals with different roles in Rugby might be able to identify, prevent, and treat concussion in the Rugby Union (rugby) system.

Why we chose you
Concussion is a concerning issue in junior sport and it affects and involves more than just the injured player. It is not uncommon for one person to have more than one role in rugby, for
example parents might coach their child’s team and also play themselves. As such, we suspect there may be some gap and/or overlap in the implementation of these strategies due to the multiple roles involved in rugby. In this study we want to hear about your knowledge and opinions regarding concussion in rugby, which may vary depending on your different roles.

**Method and participation**

The proposed research will use an online survey (www.surveymonkey.com/rugbyconcussion) to gather the demographic details of different actors (people with different roles) who are involved in the rugby community (e.g., players [14yrs+], coaches, parents, medics/first-aiders, referees, admin officers, managers/club managers, volunteers etc.). This survey also asks open ended questions about how individuals might identify, prevent, and treat concussion in their different roles. As your full responses are valued, please allow 20 to 30 minutes to complete the survey.

**Risks**

There is minimal risk associated with participation in this study, however some psychological or emotional distress may occur as the survey does ask about your knowledge of and previous experience with concussive injury. Should you feel that you need support for any mental health concern following participation in this research, please contact the University of the Sunshine Coast (USC) Psychology Clinic on (07) 5459 4515; Kids Helpline on 1800 55 1800; or Lifeline on 13 11 14.

**Expected benefits**

The results of this study will lead to a better understanding of who is affected by and involved with concussion in rugby. This will potentially influence how future guidelines are structured; the implementation of identification, prevention, and management strategies; as well as return-to-play guidelines and recommendations. Hopefully this will reduce some of the confusion associated with sport-related concussion when multiple roles are at play.

**Voluntary participation**

Participation in this study is entirely voluntary. If you do agree to participate, you can withdraw from the project at any time during the study without any comment or penalty.
Your decision to participate or not to participate, will in no way affect your current relationship with your coach or Rugby club, or with the University of the Sunshine Coast. No incentive/payback or reimbursement is being offered to participants for participation.

Confidentiality
All responses to this questionnaire will remain anonymous. If any response/s include identifiable information, these details will be changed to protect privacy. Responses will only be accessible to members of the research team, as listed at the head of this document. Survey data will be stored in a password protected computer file for the minimum prescribed 5 year period following any publication or conference paper reporting on the project. Research data may be accessed by auditors, ethics committees, or regulatory authorities. Any data from this study published in peer-reviewed research journals will not include any identifiable information.

Disclosure of funding sources
This project has applied for financial support from the University of the Sunshine Coast.

Feedback
Data will be analysed as a group, as such individual data will not be available however participants may have access to the main findings of the study by contacting the research team. This research project is the subject of Miss Clacy's PhD candidature; as such a 'by publication' thesis will be produced. A plain language summary of results can also be provided by the research team upon request, refer to the top of this document for contact details.

Further information
If you have any questions or require any further information about the present project or the subsequent longitudinal research, please do not hesitate to contact the research team. Please see the heading of this document for a full list of contact information.

Concerns or complaints
The Human Research Ethics Committee of the University of the Sunshine Coast has approved this study (S/14/662). If you have any complaints about the way this research project is being
conducted you can raise them with the Principal Researcher. If you prefer an independent person, contact the Chairperson of the Human Research Ethics Committee at the University: (c/- the Research Ethics Officer, Office of Research, University of the Sunshine Coast, Maroochydore DC 4558; telephone (07) 5459 4574; email humanethics@usc.edu.au).

**Online Survey**

By clicking on the link below, you are giving your consent to participate in this research project, and have read, understood and kept the information sheet with yourself and are satisfied that you are entering into this study with a thorough understanding of what it entails.

To give this online survey a ‘try’ please click the following link:

www.surveymonkey.com/rugbyconcussion

**Both the research team and the University of the Sunshine Coast sincerely thank you for your assistance in investigating this important area.**