EXPLORING PSYCHOLOGICAL VARIABLES BETWEEN COLLEGIATE STUDENT-ATHLETES WITH AND WITHOUT A HISTORY OF SPORT-RELATED CONCUSSION

By

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PUBLIC ABSTRACT

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Sport-related concussion (SRC) has recently become a public health concern that has garnered much national attention. One strategy to protect against negative consequences is to prevent SRC from occurring by investigating injury risk factors. Although many potential risk factors have been studied, there is minimal evidence on how SRC occurrence relates to intrinsic psychological variables. **OBJECTIVE:** The purpose of this study was to investigate the differences in risk-taking behaviors, sensation seeking needs, mood states, and personality traits between collegiate student-athletes with and without a history of SRC (i.e. 0, 1, 2+). A secondary aim of this study was determine if any of the psychological variables predicted a history of SRC in collegiate student-athletes. **DESIGN:** cross-sectional quantitative study. **SUBJECTS:** 1,252 male (n=706) and female (n=546) collegiate student-athletes from four different institutions, representing all three NCAA divisions, and 18 different sports. The SRC independent variable groups were as follows: 938 (74.9%) participants with no previous history of SRC, 205 (16.4%) participants who had sustained one previous SRC, and 109 (8.7%) participants who had sustained two or more previous SRCs. **MEASUREMENTS:** A one-time survey acquired data on demographic information, previous SRC history, and psychological variables (i.e. Barratt Impulsiveness Scale, Brief Sensation Seeking Scale, Brunel Mood Scale, Big Five Personality Inventory). **RESULTS:** Attention, motor, and total risk-taking impulsivity were significantly higher for the 2+ SRC group compared to both the 0 and 1 SRC groups. Adventure seeking scores were significantly higher for the 1 SRC group compared to the 0 SRC group, while total sensation seeking scores were higher for the 2+ SRC group compared to the 0 SRC group. Mood state and personality traits did not differ between SRC groups. **CONCLUSION:** Although mood and personality do not appear to differ based upon SRC history for this study, total risk-taking and sensation seeking scores were higher in collegiate student-athletes with a history of multiple SRC. As these variables did not differ between the 0 and 1 SRC groups, risk-taking and sensation seeking may not be important psychological variables for those sustaining a single SRC, but may be more important when dealing with a history of multiple SRCs. A prospective, longitudinal study is needed to clarify these findings and investigate if a causal relationship exists.

ABSTRACT

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Sport-related concussion (SRC) has recently become a public health concern that has garnered much national attention. One strategy to protect against negative consequences is to prevent SRC from occurring by investigating injury risk factors. Although many potential risk factors have been studied, there is minimal evidence on how SRC occurrence relates to intrinsic psychological variables. **OBJECTIVE:** The purpose of this study was to investigate the differences in risk-taking behaviors, sensation seeking needs, mood states, and personality traits between collegiate student-athletes with and without a history of SRC (i.e. 0, 1, 2+). A secondary aim of this study was determine if any of the psychological variables predicted a history of SRC in collegiate student-athletes. **DESIGN:** cross-sectional quantitative study. **SUBJECTS:** 1,252 male (n=706) and female (n=546) collegiate student-athletes from four different institutions, representing all three NCAA divisions, and 18 different sports. The SRC independent variable groups were as follows: 938 (74.9%) participants with no previous history of SRC, 205 (16.4%) participants who had sustained one previous SRC, and 109 (8.7%) participants who had sustained two or more previous SRCs. **MEASUREMENTS:** A one-time survey acquired data on demographic information, previous SRC history, and psychological variables (i.e. Barratt Impulsiveness Scale, Brief Sensation Seeking Scale, Brunel Mood Scale, Big Five Personality Inventory). **RESULTS:** Significant differences were found between previous SRC groups for attention impulsivity [$F_{(1,226)}=7.35, p=0.00$], motor impulsivity [$F_{(1,226)}=6.97, p=0.00$], and total risk-taking impulsivity [$F_{(1,227)}$=7.15,*p*=0.00] variables. Attention, motor, and total risk-taking impulsivity were significantly higher for the 2+ SRC compared to the 0 SRC group [Attention: Mean Difference (MD)=0.24,*p*=0.00,*d*=0.42; Motor: MD=0.23,*p*=0.00,*d*=0.41; Total: MD=0.18,*p*=0.00,*d*=0.41] and the 1 SRC group [Attention: MD=0.18,*p*=0.02,*d*=0.31; Motor: MD=0.20,*p*=0.01,*d*=0.35; Total: MD=0.15,*p*=0.02,*d*=0.33]. Significant differences between previous SRC groups for the boredom susceptibility [$F_{(1,207)}$=3.15,*p*=0.04], adventure seeking [$F_{(1,208)}$=5.18,*p*=0.01], and total sensation seeking [$F_{(1,214)}$=4.53,*p*=0.01] variables were also identified. Adventure seeking scores were significantly higher for the 1 SRC group compared to the 0 SRC group (MD=0.22,*p*=0.02, *d*=0.20), while the total sensation seeking score was significantly higher for the 2+ SRC group compared to the 0 SRC group (MD=0.19,*p*=0.03,*d*=0.25). No significant mood state or personality trait differences between SRC groups were found. **CONCLUSION:** Although mood and personality do not appear to differ based upon SRC history for this study, total risk-taking and sensation seeking scores were higher in collegiate student-athletes with a history of multiple SRC. As these variables did not differ between the 0 and 1 SRC groups, risk-taking and sensation seeking may not be important psychological variables for those sustaining a single SRC, but may be more important when dealing with a history of multiple SRCs. More research is needed to clarify these findings and investigate if a causal relationship exists.

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"*Education is the most powerful weapon which you can use to change the world.*"

– Nelson Mandela

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

1.1. Overview of the Problem

Sport-related concussion (SRC) has recently become a public health concern that has garnered much national attention. Concussion is an injury to the brain that is defined as "a complex pathophysiological process affecting the brain that is induced by biomechanical forces (McCrory et al., 2013)." According to statistics from the Centers for Disease Control and Prevention (CDC), about 1.6 to 3.8 million traumatic brain injuries (TBIs) occur in the United States each year (Langlois, Rutland-Brown, & Wald, 2006). An estimated 300,000 of these are diagnosed as SRCs and account for approximately 5 to 9% of all sport injuries (Gessel et al., 2007; Centers for Disease Control and Prevention, 2007; Powell & Barber-Foss, 1999; Thunnan, Branche, & Sniezek, 1998). A SRC is a subset of mild TBIs (mTBIs) that specifically occur while participating in athletics.

Having a previous history of SRC makes an individual 1.5 to 5.8 times more likely to sustain another concussive injury in the future (Guskiewicz et al., 2003; Zemper, 2003). There are a number of short-term and long-term effects that are associated with concussion. Following injury, a concussed individual may present with a unique variety of clinical symptoms (e.g. headache), physical signs (e.g. loss of consciousness), cognitive impairments (e.g. decreased reaction time), neurobehavioral changes (e.g. irritability), and/or sleep disturbances (McCrory et al., 2013). These acute issues call for physical and cognitive rest during the first few days following injury, and a student-athlete must successfully complete a graduated return to play (RTP) protocol before resuming athletic participation (McCrory et al., 2013). The majority of SRCs are self-limiting in nature and resolve within 7 to 10 days (McCrory et al., 2004).

Following a single SRC, most student-athletes are able to achieve RTP status without complications. Recovery may become more challenging when an individual sustains a second, third, or fourth SRC. Previous research has found that student-athletes with a history of three or more SRCs have poorer on-field concussion presentation (Collins et al., 2003), greater acute memory changes (Iverson, Gaetz, Lovell, & Collins, 2004), and longer recovery times (Guskiewicz et al., 2003). There is also evidence that suffering three or more SRCs may lead to more long-term issues such as neuro-physiological changes, chronic subjective symptoms, and decreased neurocognitive performance (Iverson et al., 2004; Gaetz, Goodman, & Weinberg, 2000). It is unclear if these accumulating effects of three or more SRCs are applicable to those who have only sustained one or two previous SRCs. Moreover, these investigations are considered preliminary and more research is needed to strengthen their findings and increase their generalizability across all sports and level of competition.

Of greater concern is the theory that a history of multiple SRCs may be associated with negative effects on emotional wellbeing and brain health later in life. A 2007 study by Guskiewicz and colleagues found that retired professional football players with a history of SRCs were at a 1.5 to 3 times greater risk for developing clinical depression than those who had not sustained a concussive injury during their playing years (Guskiewicz et al., 2007). A follow-up investigation found a strong dose-response relationship between SRC and the risk of depression diagnosis over a 9-year period (Kerr, Marshall, Harding, & Guskiewicz, 2012). As the number of self-reported SRC in retired professional football players increased so did the risk for clinical depression diagnosis, ranging from 3% in the “0” SRC group to 26.8% in the “10 or more” SRC group (Kerr et al., 2012). Furthermore, significant mild cognitive impairments have also been reported for 35% of a retired professional football sample who had a mean age of 64.2 years (Randolph, Karantzoulis, & Guskiewicz, 2013). This finding is much higher compared to the ≤ 5% prevalence rate of mild cognitive impairments seen in the general male population under the age of 75 (Roberts et al., 2012; Tervo et al., 2004).

In addition, chronic traumatic encephalopathy (CTE) is also being investigated as another potential long-term consequence of concussive injuries. CTE is a progressive neurodegenerative disorder that is characterized by an increased accumulation of the tau protein within the brain and is diagnosed post-mortem (McKee et al., 2009, 2010; Omalu et al., 2005, 2006, 2010). It is associated with the clinical symptoms of irritability, aggression, impulsivity, short-term memory loss, depression, and increased suicidal tendencies that usually begin 8-10 years following repetitive mild traumatic brain injuries (McKee et al., 2009). In the later stages, CTE may be mistaken for Alzheimer’s disease or frontotemporal dementia due to its association with advancing neurological abnormalities, gait and speech issues, parkinsonism, and motor neuron disease (Gavett, Stern, Cantu, Nowinski, & McKee, 2010; Gavett, Stern, & McKee, 2011; McKee et al., 2009). Although the research on late-life depression, mild cognitive impairments, and CTE has resulted with some alarming findings, it is important to note that a true causative relationship with SRC has yet to be established. Current on-going longitudinal studies are being completed in order to shed more light on these issues in the future.

1.2. Significance of the Problem

One strategy to protect against the potential short-term and long-term consequences of concussion is to prevent them from occurring. Concussion prevention can be approached in a number of different ways. One prevention strategy is to increase concussion awareness through education to players, parents, coaches, referees, and school officials involved in athletic programs. In accordance with the CDC's HEADS UP campaign, concussion management policies and action plans have been created by many states, schools, and sports league in order to help prevent, identify, and educate the general public about concussive injuries. Another approach to concussion prevention is by making changes to sports rules. For example, some of the recently proposed rule changes to decrease head impacts in football include limiting full-contact practice time and penalizing players for intentional helmet-to-helmet collisions with a defenseless opponent.

An additional way to prevent concussions, and the focus of this study, was to identify individual risk factors that make student-athletes more susceptible to concussive injuries. This information could be used to provide at-risk student-athletes with additional education and technique modifications before they are exposed to full-contact practice and game environments. The only research-confirmed risk factors for sustaining a concussion are having a history of previous concussion (Gerberich, Priest, Boen, Straub, & Maxwell, 1983; Guskiewicz, Weaver, Padua, & Garrett, 2000; Schulz et al., 2004) and female sex (Fuller, Junge, & Dvorak, 2005; Delany, Lacroix, Leclerc, & Johnston, 2002; Gessel et al., 2007; Covassin, Swanik, & Sachs, 2003). It is also speculated that adolescent and youth athletes are at a higher risk for sustaining a concussion compared to older athletes (Proctor & Cantu, 2000; Giza & Hovda, 2001; McKeever & Schatz, 2003; Buzzini & Guskiewicz, 2006), but more research is needed to confirm this theory. Although many potential risk factors have been investigated (i.e. sport, body type, playing position), there is minimal evidence on how SRC occurrence relates to psychological variables, such as risk-taking behaviors, sensation seeking needs, mood states, and personality traits.

One psychological variable that is speculated to be connected to SRC occurrence is risk-taking, which is defined as the "engagement in behaviors that are associated with some probability of undesirable results (Beyth-Maron & Fischhoff, 1997; Beyth-Maron, Austin, Fischhoff, Palmgren, & Jacobs-Quadrel, 1993; Byrnes, 2013)." There is no previous research investigating the relationship between risk-taking behaviors and SRC. There is one study by Kontos (2004) who investigated the relationship between risk-taking and the occurrence of athletic injuries in adolescent soccer athletes. Risk-taking was assessed using a nine-item Risk-Taking Behaviors Scale (RTB) that was soccer-specific and asked subjects to rank on a four-point likert scale how often they engaged in each risky soccer behaviors (i.e., hard tackles, diving headers). Assessments for previous injuries, perceived risk of future injury, and estimation of ability were also collected. Of the 260 adolescent soccer players that completed baseline assessments, 21 subjects sustained an injury that caused them to sit out of their current match, be removed from participating for a few days, or required advanced medical attention. Results indicated that self-reported risk-taking behavior was not directly related to a history of previous injuries or sustaining an acute injury during the study period. Case control analyses revealed that lower levels of estimation of ability and perceived risk were significant factors that lead to an increase in injury risk for the study sample. Additionally, higher perceived risk and a high estimation of ability decreased the risk of injury (Kontos, 2004). Overall, this study did not look at SRC specifically and was limited by its injury sample size and lack of sport diversity. It is unknown if risk-taking behaviors during athletic participation play a significant role in SRC occurrence, and much research is needed to investigate this potential relationship.

Sensation seeking is closely linked with risk-taking, and is defined as "the seeking of varied, novel, complex, and intense sensations and experiences, and the willingness to take physical, social, legal, and financial risks for the sake of such experience (Zuckerman, 1979; Zuckerman, 1994)". There are few studies that have investigated the relationship between sensation seeking and SRC or mTBIs. One study by Hollis and colleagues (2009) prospectively examined SRC and sensation seeking needs in rugby players. A cohort of 3,207 rugby players completed baseline measurements of the Sensation Seeking Survey-Form V (SSS-V) prior to their competitive season. A total of 347 concussions were recorded for 313 players during the test period with 29 of those subjects sustaining multiple concussions. Results found that subjects who had high scores on the SSS-V (IR=9.91 per 1,000 AEs) had a significantly higher concussion incidence rate compared to low to medium sensation seeking rugby players (IR=7.12 per 1,000 AEs; Hollis et al., 2009). Similar results were seen for a retrospective study on sensation seeking behaviors in young adults with and without a history of previous head injury (O'Jile, Ryan, Parks-Levy, Betz, & Gouvier, 2004). This study defined a head injury as a self-reported head trauma that resulted in some alteration of consciousness. A total of 217 undergraduate students completed a survey that included questions about previous head injuries and the SSS-V. A total of 66 subjects self-reported that they had sustained a previous head injury. An analysis of group differences found that those with a history of head injury scored significantly higher on the SSS-V thrill and adventure seeking subscale compared to non-head injury participants. There was also a trend toward significance for the SSS-V total and boredom susceptibility scores with head injury subjects attaining higher scores (O'Jile et al., 2004). Both studies concluded that there was an association in their sample populations between high sensation seeking needs and SRC or head trauma (Hollis et al., 2009; O'Jile et al., 2004). Although Hollis et al. (2009) did complete a study of SRC and sensation seeking, their sample population was limited to male rugby players. Future investigations are needed to determine if these findings are generalizable to both sexes and a variety of different sports.

The most widely investigated psychological variable in the concussion literature is mood state, specifically depression outcomes following injury. Mood is described as "a set of feelings, ephemeral in nature, varying in intensity and duration, and usually involving more than one emotion (Lane & Terry, 2000)". Two studies investigated pre- and post-injury mood states for SRC, musculoskeletal injury, and control groups of collegiate student-athletes (Mainwaring et al., 2004; Hutchison, Mainwaring, Comper, Richards, & Bisschop, 2009). Both found no differences in baseline pre-injury mood states between groups, which lead researchers to conclude that pre-injury mood state was not a risk factor for SRC in their samples of collegiate student-athletes (Mainwaring et al., 2004; Hutchison et al., 2009). Mainwaring et al. (2004) also found that collegiate student-athletes with a SRC (n=16) had significantly higher post-injury Profile of Mood State (POMS) depression, confusion, and total mood disturbance scores compared to a healthy control group (n=28). These elevated mood disturbances did return close to pre-injury baseline within a mean reassessment time frame of two-weeks following SRC (Mainwaring et al., 2004). Hutchison and colleagues (2009) built upon these findings by comparing pre- and post-injury mood states between groups of collegiate student-athletes who sustained SRCs (n=20) and those who incurred musculoskeletal injuries (n=14). Although both had similar mood profiles prior to injury, there were significant post-injury mood state differences between the SRC and musculoskeletal groups. The SRC group was characterized as having significant fatigue elevation, decreased vigor, and an overall negative mood reaction following injury, while the musculoskeletal group only showed significant increases in anger. The results of this study confirm that athletic injury causes negative mood disturbances, but athletes with SRCs react differently to their injury compared to those who sustain an injury of musculoskeletal nature (Hutchison et al., 2009). Although post-SRC depression issues are well-documented in the literature (Mainwaring et al., 2004; Hutchison et al., 2009; Guskiewicz et al., 2007; Kerr et al., 2012; Kontos, Covassin, Elbin, & Parker, 2012; Vargas, Rabinowitz, Meyer, & Arnett, 2015; Chrisman & Richardson, 2014; Roiger, Weisauer, & Kern, 2015), more research is needed on how additional mood state variables are related to SRCs (i.e., anxiety, vigor, anger). A more in-depth investigation is needed to help clarify the association between pre-injury mood states and the occurrence of SRC, as the Mainwaring et al. (2004) and Hutchison et al. (2009) studies were both limited by small sample sizes and neglected to take a history of previous SRCs into consideration.

Another psychological variable of interest is personality, which is defined as “an individual’s unique variation on the general evolutionary design for human nature, expressed as a developing pattern of dispositional traits, characteristic adaptations, and integrative life stories complexly and differentially situated in culture" (McAdams & Pals, 2006). There are a limited number of studies that have investigated personality as it relates to mTBI and other types of head injuries. One previous study on the general population examined the difference between pre-injury personality traits for mild TBI (mTBI), orthopedic injury, and control groups (Rush, Malec, Moessner, & Brown, 2004). Results found no pre-injury personality differences between groups, which lead the researchers to conclude that personality was not a predisposing factor for sustaining a mTBI in their sample (Rush et al., 2004). Another study by Collinson (2010) investigated the relationship of personality variables and the development of Post-Concussion Syndrome (PCS). Within 72-hours of an emergency room visit and a mTBI diagnosis, personality and psychological variables were assessed using the NEO-Five Factor Inventory (NEO-FFI) of personality, the Beck Depression Inventory II (BDI-II), and the State-Trait Anxiety Inventory (STAI). After the initial assessment, the researchers completed three-month and six-month follow-up phone calls where the patients verbally completed the Rivermead Post-Concussion Symptoms Questionnaire, STAI, and BDI-II. Results found that mTBI patients had a greater disposition toward neuroticism, anxiety, and depression following a concussive injury compared to a healthy control group. It was additionally found that levels of neuroticism, depression, and anxiety were higher for prolonged PCS mTBI patients compared to mTBI patients who had recovered from PCS at the six-month reassessment (Collinson, 2010). The results of these preliminary studies indicate that personality may not be a risk-factor for sustaining a mTBI, but could play an important role in post-mTBI recovery outcomes (Rush et al., 2004; Collinson, 2010).

However, no research to date has examined personality traits and SRC. Future investigations are needed to strengthen the findings from the above studies and to determine if similar personality conclusions can be made in an athletic population suffering from SRCs.

Overall, there is a lack of research on the relationship between SRC occurrence and these psychological variables. Most of the available literature is not generalizable to all sports and methodological issues limit their findings. In order for psychological variables to be considered useful for concussion prevention, a relationship between concussive injury and personality, risk-taking behaviors, sensation seeking needs, and mood states must be more clearly defined.

1.3. Purpose of the Study

The primary purpose of this study was to investigate the differences in risk-taking behaviors, sensation seeking needs, mood states, and personality traits between collegiate student-athletes with and without a history of SRC. A secondary aim of this study was determine if any of the psychological variables predicted a history of SRC in collegiate student-athletes.

1.4. Hypotheses

H1: Collegiate student-athletes with a history of SRC (i.e., 1 and 2+ SRCs) will have higher risk-taking behaviors than those who have not sustained a concussion.

H2: Collegiate student-athletes with a history of SRC (i.e., 1 and 2+ SRCs) will have higher sensation seeking than those who have not sustained a concussion.

H3: Collegiate student-athletes with a history of SRC (i.e., 1 and 2+ SRCs) will have higher mood state than those who have not sustained a concussion.

1.5. Research Questions

1. Are there personality trait differences between collegiate student-athletes with and without a history of SRC (i.e., 1 and 2+ SRCs)?
2. Do risk-taking, sensation seeking, mood, and/or personality psychological variables predict SRC history?

1.6. Operational Definition of Terms

Collegiate Student-Athlete: Any athlete that is enrolled in an academic program full-time and competes in baseball, basketball, bowling, cross country, fencing, women's field hockey, football, golf, gymnastics, ice hockey, lacrosse, rifle, women's rowing, skiing, soccer, softball, swimming and diving, tennis, track and field, volleyball, water polo, and wrestling at the National Collegiate Athletic Association (NCAA) division I, II, or III level.

Concussion: Concussion is an injury to that brain that is defined as "a complex pathophysiological process affecting the brain that is induced by biomechanical forces (McCrory, 2013)". This is also known as a mild traumatic brain injury (mTBI).

Sport-Related Concussion: A concussion or mTBI that occurs while playing sports.

History of Concussion: A self-report of concussions that were diagnosed by a physician, athletic trainer, or other qualified healthcare provider.

Mood States: Mood is described as "a set of feelings, ephemeral in nature, varying in intensity and duration, and usually involving more than one emotion" (Lane & Terry, 2000).

Personality Traits: Personality is defined as " an individual's unique variation on the general evolutionary design for human nature, expressed as a developing pattern of dispositional traits, characteristic adaptations, and integrative life stories complexly and differentially situated in culture" (McAdams & Pals, 2006).

Risk-Taking Behaviors: Risk-taking is defined as the "engagement in behaviors that are associated with some probability of undesirable results" (Beyth-Marom & Fischhoff, 1997; Beyth-Marom et al., 1993; Byrnes, 2013; Furby & Beyth-Marom, 1992

Sensation Seeking Needs: Sensation seeking is defined as "the seeking of varied, novel, complex, and intense sensations and experiences, and the willingness to take physical, social, legal, and financial risks for the sake of such experience" (Zuckerman, 1979; Zuckerman, 1994).

Sport-Related Concussion: A sports-related concussion is a concussion that occurs during athletic participation. These may occur in off-season training, practices, competitions, or any activity that is related to sport.

1.7. Limitations

This study was limited by its self-reported nature and the assumption that subjects will answer truthfully to all survey items. It was also limited by the subject's capacity to remember their previous history of SRCs as no medical documentation was obtained to verify injury occurrence. Additionally, only collegiate student-athletes acted as participants for this study; therefore, results are not generalizable to adolescent, high school, or professional sports. The participants were also be recruited from Michigan and Pennsylvania colleges and universities and are not a representation of the entire United States collegiate student-athlete population.

CHAPTER 2

REVIEW OF LITERATURE

2.1. Introduction

This review of literature investigates the previous research in areas related to the current study, including: concussion, risk-taking, sensation seeking, mood, and personality. The extensive concussion overview encompasses information on the definition, epidemiology, mechanism, pathophysiology, diagnosis, treatment, return to play, and long-term effects associated with concussive injuries. The remaining sections on risk-taking, sensation seeking, mood, and personality focus on defining each psychological component, investigating how they have been previously studied in sport, and examining their relationship and importance to sports-related concussion. The overall purpose of this literature review is to provide a thorough discussion on how risk-taking, sensation seeking, mood, and personality have been previously studied in sports-related concussion literature and what still needs to be addressed in future research.

2.2. Concussion Definition

There are discrepancies in the overall definition and classification of concussions. An early definition of mild traumatic brain injury (mTBI) comes from the Committee on Head Injury Nomenclature of the Congress of Neurological Surgeons in 1966. They categorized concussion as being a post-traumatic, clinical syndrome that is caused by mechanical forces and characterized by the immediate and transient impairment of neural functions (American Academy of Neurology, 1997). Another proposed description for concussion defines it as a ‘trauma-induced alteration in mental status that may or may not involve loss of consciousness (LOC) (Kelly et al, 1991).

Increasing attention to sports-related concussions and the need for universal consensus prompted the first International Conference on Concussion in Sport in 2001 in Vienna. This committee included 10 concussion experts from around the world that made up the Concussion in Sport Group (CISG) (Aubry et al., 2002). The CISG's purpose was to develop a universally agreed upon, systematic approach to concussion management. Their first agenda was to review previously proposed research definitions and develop a consensus definition of concussion (Aubry et al., 2002). Since the initial meeting, there has been a 2nd (Prague, 2004), 3rd (Zurich, 2008), and 4th (Zurich, 2012) International Conference on Concussion in Sport (McCrory et al., 2005; McCrory et al., 2009; McCrory et al., 2013). The number of concussion experts participating in the conference has grown from the initial 10 to a total of 28 in the 4th CISG, which has resulted in an evolution of the concussion definition. In the most recent Zurich Consensus summary and agreement statement, the definition was derived from a panel discussion that focused on the separations between concussion, mTBI, and TBI. "Concussion" and "mTBI" are frequently used interchangeably in research within the United States, but refer to different injures in other countries. Due to this difference, it was determined that the term "concussion" should be used to refer to a subset of TBI that have occurred in a sporting context (McCrory et al., 2013). The complete concussion definition from the 4th CISG is as follows:

Concussion is a brain injury and is defined as a complex pathophysiological process affecting the brain, induced by biomechanical forces. Several Common features that incorporate clinical, pathologic and biomechanical injury constructs that may be utilized in defining the nature of a concussive head injury include:

1. Concussion may be caused either by a direct blow to the head, face, neck, or elsewhere on the body with an 'impulsive' force transmitted to the head.
2. Concussion typically results in the rapid onset of short-lived impairment of neurological function that resolves spontaneously. However, in some cases, symptoms and signs may evolve over a number of minutes to hours.
3. Concussion may result in neuropathological changes, but the acute clinical symptoms largely reflect a functional disturbance rather than a structural injury and, as such, no abnormality is seen on standard structural neuroimaging studies.
4. Concussion results in a graded set of clinical symptoms that may or may not involve loss of consciousness. Resolution of the clinical and cognitive symptoms typically follows a sequential course. However, it is important to note that in some cases symptoms may be prolonged. (McCrory et al., 2013)

2.3. Epidemiology of Concussion

According to statistics from the Center for Disease Control and Prevention (CDC), about 1.6 to 3.8 million TBIs occur in the United States each year (Langlois, Rutland-Brown, & Wald, 2006). Of those TBIs, an estimated 300,000 are sports-related concussions, which account for approximately five to nine percent of all sport injuries (Gessel et al., 2007; CDC, 2007; Powell & Barber-Foss, 1999; Thunnan, Branche, & Sniezek, 1998). It is important to note that these statistics do not take into account the number of concussions that go undiagnosed and are most likely higher than reported (McCrea, Hammeke, Olsen, Leo, & Guskiewicz, 2004; McLeod, Bay, Heil, & McVeigh, 2008; Williamson & Goodman, 2006; Llewellyn, Burdette, Joyner, & Buckley, 2014;

Register-Mihalik et al., 2012; Kerr et al., 2014). It is also reported that there are approximately 1.37 million TBI emergency room visits in the United States each year with an associated estimate of medical costs around $60 billion collectively (Faul, Xu, Wald, & Coronado, 2010; Finkelstein, Corso, & Miller, 2006).

Guskiewicz and colleagues (2000) completed an investigation into the epidemiology of concussion in both collegiate and high school football players. Data was collected over a three-year time period by 242 high school, division-I, division-II, and division-III certified athletic trainers (ATC) who completed a concussion report form immediately following injury. In addition, ATCs also completed an overall school injury information summary at the completion of the sport season. Of the 17,549 football athletes included in this study, 5.1% (n=888) sustained at least one concussion, out of those who sustained a concussion, 14.7% (n=131) sustained a second concussive injury in the same season. Those who sustained a concussion were at a three times greater risk for sustaining another concussion that same season compared to their non-injured counterparts. Results also revealed that the incidence of injury was significantly higher for high school (5.6%) and division-III collegiate (5.5%) athletes compared to division-I (4.4%) and division-II (4.5%) collegiate athletes. When taking only athlete-exposures (AE) dealing with contact-related play into consideration, the overall rate of concussions was 1.28 per 1,000 AEs. Additionally, concussions occurred more frequently in games (59.9%) with offensive linemen, defensive backs, and linebackers being the most likely to be injured (Guskiewicz, Weaver, Padua, & Garrett, 2000).

Although football has been the main focus of concussion research in the past, more recent studies have focused on a variety of male and female sports. In 2007, Gessel et al. investigated concussions among United States high school and collegiate athletes from 2005-2006 competing in nine different sports (football, boys' soccer, girls' soccer, volleyball, boys' basketball, girls' basketball, wrestling, baseball, softball). This study used concussion data that was collected via the Reporting Information Online (RIO) internet-based injury surveillance system in nine high schools spanning over one academic year. Injury rates were directly compared to one year's worth of concussion information from the NCAA Injury Surveillance System (ISS). In the high schools, there were 4,431 injuries reported with 8.9% (n=396) being concussions and occurring predominately during competition (65.4%). In the corresponding college sport data, there were 8,293 injuries reported with a total of 482 (5.8%) concussions. An overall high school injury rate of 0.23 concussions per 1,000 AEs was reported, with a higher rate of 0.53 per 1,000 AEs during competitions. For both the high school and collegiate settings, football had the highest concussion injury rate with 0.47 (High School) and 0.61 (College) per 1,000 AEs. Girls' soccer had the second highest concussion injury rates with 0.36 (High School) and 0.63 (College) followed by boys' soccer with 0.22 (High School) and 0.49 (College). Overall, the rate of concussion was higher in the collegiate sports (0.43) than in high school sports (0.23). In sports that are played by both sexes, females had a higher rate of concussion that represented a greater portion of their total injuries compared to high school and collegiate males who played similar sports (Gessel et al., 2007). High school females who played soccer (0.36/1,000 AEs) and basketball (0.21) had a higher rate of concussion compared to high school males who played soccer (0.22) and basketball (0.07) (Gessel et al., 2007). Collegiate female athletes who played soccer (0.63/1,000 AEs) and basketball (0.43) had a higher rate of concussion compared to high school males who played soccer (0.49) and basketball (0.27)(Gessel et al., 2007).

A 2012 study also used the High School RIO database to investigate concussion epidemiology in 20 different high school sports from 2008-2010 and reported a total of 1,936 concussions in 7,780,064 AEs (Marar, McIlvain, Fields, & Comstock, 2012). This study was unique compared to other concussion epidemiology research because it focused on more than just the traditional sports of football, soccer, wrestling, basketball, volleyball, and softball/baseball. It included injury data from additional sports, such as: boys' ice hockey, girls' field hockey, cheerleading, boys' and girls' lacrosse, boys' and girls' swimming/diving, and boys' and girls' track and field. Even with 11 extra sports, the overall injury rate was similar to those found previously with 0.25 concussions per 1,000 AEs (Marar et al., 2012). Marar and colleagues also replicated Gessel and colleagues (2007) findings that the injury rates are higher during competition (0.64) compared to practice (0.10) and that females (0.17) have a higher concussion injury rate than males (0.10) in sex-comparable sports (Marar et al., 2012). Football again had the highest incidence of concussion (0.64), but this study found that boys' ice hockey (0.54) and boys' lacrosse (0.40) came in second and third instead of girls' and boys' soccer as reported by Gessel et al (2007).

In a prospective 11-year study on high school concussion trends, it was found that concussion diagnosis rates have increased by 15.5% annually since 1997-1998 to 2007-2008 (Lincoln et al., 2011). The overall concussion rate for all sports went from 0.12 per 1000 AEs in 1998 to an increased 0.49 per 1000 AEs in 2008. They also found that wrestling had the highest mean increase in concussions at 27% annually and the second highest was cheerleading with 26% mean annual increases. Excluding wrestling, individual male sports had mean annual increases in concussions from 8% to 17%. These annual increases were even higher for female sports with individual annual increases in concussions of 14% to 26%. Overall, female sports (21%) had a greater annual increase in concussions compared to males (14%) (Lincoln et al., 2011). It is imperative to consider the increase in collision-sport participation, improvements to concussion identification and management, media coverage of concussion, and new concussion state laws that have increased the general awareness of concussion and how they may be supporting factors for the increasing trend of concussion diagnosis (Lincoln et al., 2011).

In general, a number of concussion epidemiology trends have emerged repetitively in the literature. First, the majority of concussions occur in football, wrestling, girls' soccer, boys' soccer, and girls' basketball in the United States (Harmon et al., 2013; Gessel et al., 2007; Powell & Barber-Foss, 1999; Lincoln et al., 2011; Schulz et al., 2004). Second, injury rates and the likelihood of a concussion occurring are higher in competitions than in practice (Gessel et al., 2007; Lincoln et al., 2011; Marmar et al., 2012). Third, females sustain a higher number of concussions compared to males in sex-comparable sports (Harmon et al., 2013; Gessel et al., 2007; Lincoln et al., 2011; Marmar et al., 2012; Covassin, Swanik, & Sachs, 2003; Dick, 2009). Fourth, having a concussion previously is associated with a two to 5.8 times higher risk of sustaining a subsequent concussion (Harmon et al., 2013; Schulz et al., 2004; Colvin et al., 2009; Emery et al., 2011; Kristman et al., 2008; Zemper, 2003). Finally, the overall concussion injury rate in high school sports is 0.23-0.25 per 1,000 AEs (Gessel et al., 2007; Lincoln et al., 2011; Marar et al., 2012).

2.4. Mechanism of Concussion

The basic mechanism of injury for a concussion is the forceful acceleration or deceleration of the unrestrained head where linear and/or rotational forces are transmitted to the brain by either direct and/or inertial loadings (Barth, Freeman, Broshek, & Varney, 2001; Harmon et al., 2013; Meaney & Smith, 2011). There can be many different head motions that can result from being struck in the head by a moving object or by striking the head on a stationary object, which makes every concussion-causing mechanism unique (Meany & Smith, 2011). Concussions are difficult to protect against because the brain and skull are not one continuous unit that constantly travel at the same rate. The brain is surrounded by cerebral spinal fluid, which gives it the freedom of movement within the skull cavity (Viano et al., 2005). When an external force is applied to the head, the skull suddenly stops while the brain continues to move in the cerebral spinal fluid in the intended direction of travel. The brain will then make unintentional contact with the inside of the skull during high-speed deceleration before coming to a stop. Based upon this mechanism, concussions may further be described as either a coup or countercoup mechanism based on the location of collision and pain (Drew & Drew, 2004). A coup injury is identified by pain and internal brain impact at the site of external contact, and a countercoup injury is identified by pain and internal impact on the opposite side of the cranium from where the external contact occurred (Drew & Drew, 2004).

Based upon the biomechanical movements of the neck, head, and brain at the moment of impact, there are linear and rotational accelerations that occur during a concussive event (Meany & Smith, 2011). The linear acceleration of the brain during impact has been found to be correlated with an internal brain pressure response in early animal models (Gurdjian, Lissner, Evans, Patrick, & Hardy, 1961; Thomas, Roberts, & Gurdjian, 1966; Nahum, Smith, & Ward, 1977). Transient increases in cranial pressure causes neurological dysfunctions with the level of dysfunction being directly associated to the level of pressure achieved from injury (Lindgren & Rinder, 1966). A shearing mechanism can also cause concussion-like symptoms, which is associated with rotational forces that are common during head impact and result in the disruption of axonal bridges between the cortex and midbrain (Meythaler, Peduzzi, Eleftheriou, & Novack, 2001; Meany & Smith, 2011). Further investigations into shear-induced tissue damage found that rotational acceleration is the principal mechanism of concussive injuries, and that the presence of a rotational component increases the likelihood of LOC (Gennarelli et al., 1982; Adams, Graham, Murray, & Scott, 1982; Ommaya & Gennarelli, 1974).

In recent years, an emphasis has been placed on concussion occurrence in high school and collegiate football. A study by Broglio and colleagues (2011) used the Head Impact Telemetry System to count and analyze the number of head impacts that 95 high school football players endured over a four-year period. Investigators collected data on 101,994 impacts in 190 practices and 50 games with a mean of 652 impacts per player in a 14-week season (Broglio et al., 2011). The overall incidence of concussion in high school athletics is estimated to be around 63,000 per year across all sports, which represents 5.5% of all athletic injuries (Powell & Barber-Foss, 1999). In a similar study with collegiate football athletes, results showed that players sustained an average of 5,416 head impacts in a typical four-year career (Schnebel, Gwin, Anderson, & Gaitlin, 2007).

A number of studies have also been completed in an attempt to identify an injury force threshold for concussion, as well as to track real-time head accelerations at the time of injury. Between 1996 and 2001, Pellman, Viano, Tucker, Casson, and Waeckerle (2003) analyzed video surveillance from 182 concussive National Football League (NFL) injuries to recreate 31 impacts in a laboratory setting using helmeted dummies that underwent the same velocity, direction, and head kinematics as the game injury scenarios. Pellman and colleagues (2003) found that peak linear head acceleration during concussive injury was 98±28 g resulting from impacts primarily on the side of the facemask and on the side of the helmet. The mean rotational acceleration of 6,432 rad/s^2 was also found for the 31 concussion reenactments. The authors proposed that concussions occur in helmeted impacts between 70-75 g (Pellman et al., 2003), which was lower than the 80-90 g threshold range set forth by Gurdjian in 1972. This threshold was based upon low-speed video capture, reenactments of injury using non-human subjects, a small number of cases, and only using footage of elite athletes. For these reasons, this information may not be accurate or generalizable to the entire athletic population (Guskiewicz & Mihalik, 2011).

Four recent studies have investigated concussion injury threshold and real-time head impacts in football by using the Head Impact Telemetry System (HITS) software (Mihalik, Bell, Marshall, & Guskiewicz, 2007; Guskiewicz et al., 2007; Broglio et al., 2010). Mihalik and colleagues tracked 72 collegiate football players with HITS accelerometers embedded in their helmets during the 2005 and 2006 NCAA football seasons. A total of 82,026 head impacts were recorded with 57,024 being 10 g or greater. Overall, results showed that the average head impact frequently sustained by the football players was between 21 to 23 g. Offensive linemen had the greatest number of head impacts (20,256) and highest mean linear acceleration forces (22.89 g). The largest linear acceleration forces were sustained on the top of the helmet (29.22 g), while the most frequently recorded impact location was on the front of the helmet with 20,450 hits. Only 1,858 impacts (2%) were recorded that were greater than 80 g and considered to be above the "injury threshold" of 70-75 g (Pellman et al., 2003), and of those only seven (<0.35%) resulted in diagnosed concussions (Mihalik et al., 2007).

A companion study by Guskiewicz and colleagues (2007) encompassed the 2004-2006 football seasons. The HIT system was fitted into Riddell VSR-4 and Revolution football helmets and head impacts were tracked for all practices, scrimmages, and games in real time for 88 collegiate football athletes. Researchers recorded 104,714 total impacts, which resulted in a total of 13 concussions. Results found an average magnitude of all concussive impacts to be 102.8 g. Concussive linear acceleration impacts ranged from 60.51 to 168.71 g and rotational acceleration impacts varied greatly from 163.35 to 15,397.07 rad/s^2 across all 13 recorded concussive injuries. Concussive impact locations included the top, front, back, and right side of the helmet with almost half (n=6) of the recorded concussions occurring from impacts to the top of the head. These findings suggest that a concussion can occur at varying magnitudes and impact locations (Guskiewicz et al., 2007).

Similar to Mihalik et al. (2007) and Guskiewicz et al. (2007), Broglio and colleagues (2010) examined 78 high school football players who wore the HITs helmet sensors from 2005 to 2008. A total of 54,247 impacts were recorded above 15 g, which yielded 13 diagnosed concussions. The mean linear acceleration per impact was 25.1 g with an average of 24.2 impacts occurring during practices and 26.1 impacts occurring during games. The mean rotational acceleration was 1,627.1 rad/s^2 per impact. Of the 13 concussive cases, rotational acceleration (5,582.3 rad/s^2), linear acceleration (96.1 g), and impact location (front, side, or top) were the most important variables for predicting concussion (Broglio et al., 2010). These mean findings for high school athletes were similar to those found by Pellman et al.'s (2003) NFL concussion laboratory reenactments and Guskiewicz et al.'s (2007) investigation with collegiate football players.

Beckwith and colleagues (2013) completed a large-scale study over a six-year period from 2005 to 2010 that included 1,208 collegiate and high school football players that wore the HIT system in their helmets. A total of 161,732 head impacts were recorded in 10,972 player days that resulted in 105 identified concussive injuries. Of the concussions, 66.6% occurred during games or scrimmages with symptoms lasting for 5.9±7.4 days from the time of injury. The authors found that the number of head impacts and their kinematic measures were greater on days when a concussion was diagnosed compared to days without injury. For the 95th percentile, the median peak linear acceleration on non-concussion days was 63.5 g compared to 82.0 g on concussion days. The median peak rotational acceleration on the non-concussion days was 2,761 rad/s^2 compared to 3,376 rad/s^2 on the days of diagnosed concussions. Additionally, the head impacts that were sustained immediately prior to a concussive event was identified had a mean severity of 112.1±35.4 g peak linear acceleration and 2,253±2,287 rad/s^2 of peak rotational acceleration (Beckwith et al., 2013).

Overall, there is still too much variation of linear acceleration, rotational acceleration, and impact location between injury cases. In a summary paper on the biomechanics of sport concussion and the injury threshold, Guskiewicz and Mihalik (2011) concluded that an overall concussion threshold cannot be identified due to individual variations between athletes and that the use of technology for concussion diagnosis, behavior modification, and improved mechanics should be further investigated before it becomes standard practice.

2.5. Pathophysiology of Concussion

Following a concussive event, the homeostasis of the brain is disrupted by a complex cascade of neurochemical and neurometabolic events that are triggered by the stretching and damage done to the neuronal and axonal tissues (Barkhoudarian, Hovda, & Giza, 2011; Signoretti, Lazzarino, Tavazzi, & Vagnozzi, 2011). There is an uncontrolled release of neurotransmitters that cause an ionic flux and the binding of excitatory cells (glutamate) to N-methyl-D-aspartate receptors (Faden, Demediuk, Panter, & Vink, 1989; Katayama, Becker, Tamura, & Hovda, 1990). This causes a depolarization of the neuronal tissue and is characterized by the increase in calcium and decrease in potassium levels, which triggers changes in the cellular physiology (Giza & Hovda, 2001; Katayama et al., 1990; Signoretti et al., 2011). The sodium-potassium pump attempts to control the influx of extracellular potassium and intracellular calcium by using an increased amount of adenosine triphosphate (ATP), which triggers an influx in glucose metabolism that results in a cellular energy crisis within the brain (Giza & Hovda, 2001). The increase in glucose metabolism also leads to increased lactate production with concussions (Nilsson & Ponten, 1977; Yang, DeWitt, Becker, & Hayes, 1985; Meyer, Kondo, Nomura, Sakamoto, & Teraura, 1970), which has been thought to leave neurons more vulnerable to a second injury (Becker & Jenkins, 1987). There is additional evidence that there is a 50% reduction of cerebral blood flow following a percussive head injury, which typically couples with neuronal activity and cerebral glucose metabolism in normal circumstances (Yuan, Prough, Smith , & DeWitt, 1988; Velarde, Fisher, Hovda, Adelson, & Becker, 1992; Doberstein, Velarde, Bardie, Hovda, & Becker1992).

This process occurs quickly following injury, and has been found to last somewhere from 30 minutes to 4 hours in rat models (Yoshino et al., 1991). When the hypermetabolic process ends, it is replaced with a period of decreased metabolism and depolarization that creates a state that resembles depression (Giza & Hovda, 2001; Kubota et al., 1989; Somjen & Giacchino, 1985). The energy crisis and metabolic depression are responsible for the observed cognitive deficits and compromised synaptic plasticity, but over time these biochemical changes in the brain are reversible for sports-related concussion (Tavazzi et al., 2005; Wu, Ying, & Gomez-Pinilla, 2009). In 2001, Giza and Hovda used information from over 100 articles to determine the primary elements of the pathophysiologic cascade following concussion. Below is their proposed list of events:

1. Nonspecific depolarization and initiation of action potentials.
2. Release of excitatory neurotransmitters (EAAs).
3. Massive efflux of potassium out of the cell.
4. Increased activity of membrane ionic pumps to restore homeostasis.

5. Hyperglycolysis to generate more adenosine triphosphate to fuel the ionic pumps.
6. Lactate accumulation.
7. Calcium influx and sequestration in mitochondria leading to impaired oxidative metabolism.
8. Decreased energy (ATP) production.
9. Calpain activation and initiation of apoptosis. (Giza & Hovda, 2001)

A specific component of the neurometabolic cascade that Giza and Hovda focused on was the axonal events that occur following concussion. These include the disruption and calcium influx (Pettus, Christman, Gliebel, & Povlishock, 1994; Povlishock & Pettus, 1996; Mata, Staple, & Fink, 1986), neurofilament compaction (Sternberger & Sternberger, 1983; Nakamura et al., 1990; Nixon, 1993), break down of microtubles (Pettus & Povlishock, 1996; Maxwell & Graham, 1997) and accumulation of organisms that are normally transported by the axons, and the swelling and eventual separation of the damaged axon (Maxwell & Graham, 1997; Povlishock & Christman, 1995). See Figure.1 for a visual depiction of the neurometabolic cascade following concussion as described above.

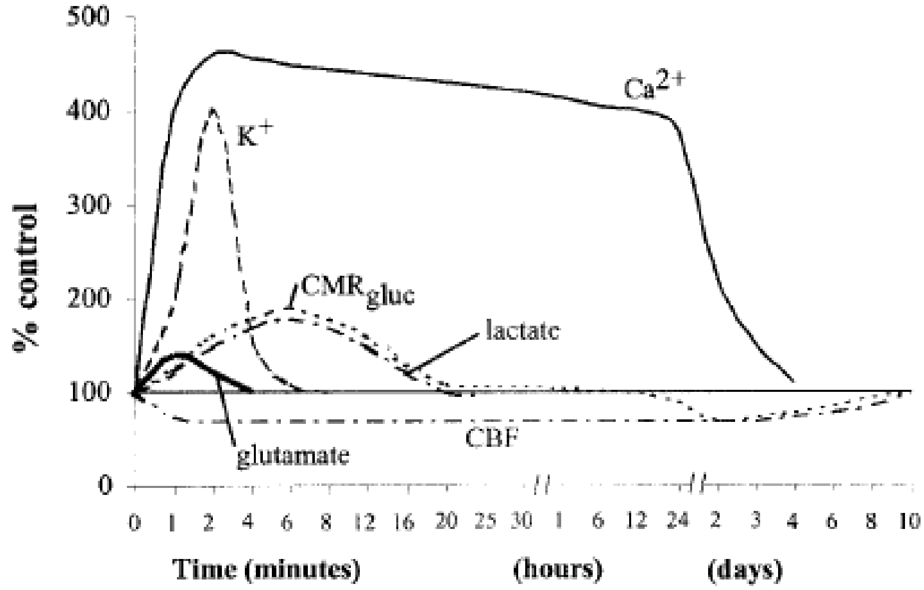


Figure 1. The Neurometabolic Cascade Following Concussion

K^+, potassium; Ca^{2+}, calcium; CMRgluc, oxidative glucose metabolism; CBF, cerebral blood flow. From "The Neurometabolic Cascade of Concussion," by C. Giza and D. Hovda, 2001, *Journal of Athletic Training, 36,* p. 229.

2.6. Diagnosis of Concussion

Evaluating and diagnosing sports-related concussion can be complicated as each individual and injury presents itself with a unique set of clinical signs and symptoms. A multi-faceted approach should be used in concussion management that revolves around sound clinical judgment from the entire sports medicine team (Broglio et al., 2014; Harmon et al., 2013; McCrory et al., 2013). In addition to taking a thorough previous concussion history, the initial stage of concussion management consists of collecting individual baseline performances on variables, such as self-reported symptoms, motor control, mental-status, and neurocognitive function, prior to a concussive event (Broglio et al., 2014; Harmon et al., 2013). This information represents the normal brain function of the athlete in an uninjured state, and can be used as a point of comparison when a concussive injury occurs. It is recommended that baseline testing be conducted on an annual basis (Broglio et al., 2014), especially in youth athletes whose brains are still actively developing (Yakovlev & Lecours, 1967; Hunt & Ferrara, 2009). When limited resources are available, baseline testing priority should be given to those who play contact/collision sports or have a history of concussion, learning disabilities, or migraine disorders (McCrory et al., 2009; Collie, Darby, & Maruff, 2001). It is important to note that post-injury reassessments by concussion management tools should not be used to diagnose a concussion or return an athlete to play, but should be used to supplement the information found in the clinical examination (Broglio et al., 2014).

2.6.1. *Symptoms*

Using some form of standardized symptom checklist is recommended as they have been found to have good sensitivity to concussions (Broglio, Macciocchi, & Ferrara, 2007; McCrea et al., 2005; Iverson, Brooks, Ashton, & Lange, 2010). A number of options are available for symptom monitoring, including the Post Concussion Symptom Scale (Lovell, 1999; Lovell & Collins, 1998; Lovell et al., 2006), Head Injury Scale (Piland, Motl, Ferrara, & Peterson, 2003), Concussion Symptom Inventory (McCrory et al., 2013; Randolph et al., 2009), and Sport Concussion Assessment Tool (CDC, 2011; McCrory et al., 2013). Subjective symptom information provided by the athlete after a suspected concussive event can be a key indicator for clinical diagnosis (McCrory et al., 2013), but there are some limitations to consider (Broglio, Macciocchi, & Ferrara, 2007). Dehydration or the feelings of completing a strenuous workout can be misinterpreted as a concussion if the mechanism of symptom onset is unclear

(Guskiewicz et al., 2007; Kashluba, Casey, & Paniak, 2006). Additionally, athletes are aware that reporting concussion symptoms may result in their removal from play, so they may purposely underreport their symptoms in order to stay in the game (McCrory et al., 2004).

The most commonly reported symptoms of concussion are headache, fatigue, feeling slowed down, drowsiness, difficulty concentrating, feeling mentally foggy, and dizziness. (Lovell et al., 2006; Meehan, d'Hemecourt, & Comstock, 2010; Marar et al., 2012; Makdissi et al., 2010; Benson, Mohtadi, Rose, & Meeuwisse, 1999) Complete LOC has been considered a key identifier of concussion in the past; however, only 10% of all concussive injuries report having LOC (Guskiewicz, Weaver, Padua, & Garrett, 2000; McCrory et al., 2013; Meehan, d'Hemecourt, & Comstock, 2010; Benson et al., 1999; Collins et al., 2003; McCrea et al., 2005; Mansell et al., 2010). Athletes may report brief altered consciousness, but true LOC is rare. Concussion symptoms are categorized as somatic, cognitive, or emotional (Kontos, 2012). Somatic symptoms are those that physically affect the body and include headache, nausea, vomiting, visual disturbances, sensitivity to light/noise, sleep disturbances, and balance problems. Cognitive symptoms affect the mental abilities and processes, which can be seen when fogginess, confusion, difficulty concentrating, and memory loss are present following a concussion. Emotional symptoms are those causing a change in personal lability such as inappropriate emotional outbursts, irritability, nervousness, personality changes, sadness, anger, depression, and anxiety (McCrory et al., 2013). In about 80 to 90% of cases symptom resolution occurs within seven to 10 days following injury (Meehan, d'Hemecourt, & Comstock, 2010; Marar et al., 2012; Makdissi et al., 2010; McCrea et al., 2005; Frommer et al., 2011).

2.6.2. *Sport Concussion Assessment Tool-3*

On-field evaluation of concussion can be difficult because there is no single "gold standard" of assessment and diagnosis for this heterogeneous injury (Guskiewicz et al., 2013). In an attempt to help standardize the assessment and patient education of concussions, the Sport Concussion Assessment Tool (SCAT) was introduced at the 2nd International Conference on Concussion in Sport (McCrory et al., 2004). The SCAT was developed by combining clinical expertise with eight previously existing concussion assessment tools. The standardized assessment of concussion (SAC) (McCrea, 2001), management of concussion sports palm card (Kelly & Rosenberg, 1997), and Maddocks questions (Maddocks, Dicker, & Saling, 1995) were a few of the assessments included in the SCAT. In 2008, the SCAT was modified into the SCAT2 by the CISG using current scientific evidence and was available in two forms, one for medical practitioners and an abbreviated version for lay individuals to help with sideline identification of concussions (McCrory et al., 2009). Guskiewicz and colleagues (2013) reviewed the existing literature on the SCAT/SCAT2 and made a number of recommendations for modifications to help refine the next version of the assessment. The SCAT3 (age 13 years or older), Child SCAT3 (age 12 or younger), and Concussion Recognition Tool were highlighted in the consensus statement from the 4th International Conference on Concussion in sport to be used for the clinical assessment of concussions (McCrory et al., 2013). The SCAT3 is recommended for use by the CISG (McCrory et al., 2013), the National Athletic Trainers Association (NATA) (Broglio et al., 2014), and the American

Medical Society (Harmon et al., 2013) as an aid for concussion management. The SCAT3 includes the following components: previous concussion history, glasgow coma scale (GCS), Maddocks Score, PCSS, SAC, neck examination, modified Balance Error Scoring System (BESS), upper limb coordination, and SAC delayed recall (McCrory et al., 2013). This assessment is most useful when compared to individual baseline performance, and post-injury assessments should be done no sooner than 15-minutes following removal from activity in order to evade the influences of physical fatigue (Guskiewicz et al., 2013).

2.6.3. *Balance Error Scoring System*

Although force plates and the Sensory Organization Test (SOT) can provide accurate balance measurements in a controlled environment, these are not cost effective and suitable for measuring postural stability on the sideline of an athletic event. The BESS is frequently used for balance assessment in the clinical sports medicine setting because it is portable, low in cost, easy to administer, sensitivity to concussive injuries, and has moderate to good reliability (McCrea et al., 2005; McCrea et al., 2003; Bell, Guzkiewicz, Clark, & Padua, 2011). The BESS challenges postural control by having individuals stand in three different stances on both a firm surface and unstable (medium-density foam) surface. The first is a double-leg stance where feet are together. The second is single-leg stance where individuals stand on their non-dominant foot. The final stance is tandem which is when the non-dominant foot is placed directly behind the dominant foot. Balance is assessed for 20-seconds with the eyes closed and hands on hips for all stances on both the firm and unstable surfaces. Performance is objectively measure by the number of errors that occurred during each 20-second trial. BESS errors include: moving the hands off the iliac crests, opening the eyes, stepping/stumbling/falling, abduction or flexing of the hip beyond 30 degrees in single leg stance, lifting the forefoot or heel off of the testing surface, or remaining out of the proper testing position for greater than five seconds (Riemann, Guskiewicz, & Shields, 1999).

Previous research using force plates and the BESS have found postural stability deficits that last roughly 72-hours following a concussive injury (Guskiewicz, 2001; Guskiewicz, Ross, & Marshall, 2001; Guskiewicz, 2003; Cavanaugh et al., 2005; Cavanaugh et al. 2006). Guskiewicz, Ross, and Marshall (2001) completed a study that investigated the postural stability following concussion in collegiate athletes. Subjects (n=36) underwent pre-season SOT and BESS baseline testing and were given a matched control following a concussive event. The concussed subject and their matched control were reassessed on the SOT and BESS at days one, three, and fives following injury. Results found that injured subjects had significant decreases in postural stability at day one compared to their own baselines and the performance of their matched control. Return back to SOT and BESS baselines for the concussed subjects occurred between days one and three post-injury (Guskiewicz, Ross, & Marshall, 2001). Due to these findings, a balance evaluation is included in the sideline management of concussion to assess for abnormalities in motor control (McCrory et al., 2013; Broglio et al., 2014).

2.6.4. *Computerized Neurocognitive Assessments*

Computerized examinations have made traditional paper and pencil neurocognitive test batteries more portable and convenient for sports medicine use. The following are computer-based neurocognitive examinations used in athletic settings:

Immediate Post-Concussion Assessment and Cognitive Testing (ImPACT), Cogstate Axon, Concussion Vital Signs, Vigil Continuous Performance Test (VIGIL), Automated Neurocognitive Assessment Metrics (ANAM), and Headminder Concussion Resolution Index (CRI) (Broglio et al., 2014). Regardless of the assessment being used, neurocognitive baseline and post-injury assessments should occur in similar environments that are quiet and non-distracting. When a concussion occurs, the resolution of self-reported symptoms should be the indicator to begin post-injury neurocognitive testing in order to protect against potential practice effects (McCrory et al., 2013; Broglio et al., 2014; Broglio, Macciocchi, & Ferrara, 2007; McCrea, 2005).

Computerized neurocognitive tools were once considered a pivotal component for concussion diagnosis (Aubry et al., 2002), but their reliability has been found to vary between different studies and test-retest time intervals (Elbin, Schatz, & Covassin, 2011; Collie et al., 2003; Iverson, Lovell, & Collins, 2005; Broglio, Ferrara, Macciocchi, Baumgartner, & Elliot, 2007; Schatz, 2010; Nakayama, Covassin, Schatz, Nogle,, & Kovan, 2014; Resch et al., 2012). For example, both Broglio et al. (2007) and Nakayama et al. (2014) assessed the test-retest reliability of the ImPACT neurocognitive test battery from baseline to day 45 and from day 45 to day 50. Broglio et al. (2007) found ICC-values of 0.23 from baseline to day 45 and 0.40 from day 45 to day 50 for verbal memory. Nakayama et al. (2014) found substantially higher results with ICC-values of 0.76 from baseline to day 45 and 0.69 from day 45 to day 50 for the same variable. The major difference between these two studies is that Nakayama and colleagues (2014) only administered the ImPACT at baseline, day 45, and day 50, while Broglio et al.'s (2007) subjects took the ImPACT, Headminder CRI, and Concussion

Sentinel at each session. The consecutive administration of multiple neurocognitive tests may have caused a mental fatigue of the participants and could explain the result discrepancies between the two studies. Overall, it is important to emphasize that computerized neurocognitive tests should never be used as the sole resource for concussion diagnosis, but should be used as a supportive tool in conjunction with a clinical evaluation (McCrory et al., 2013; Broglio et al., 2014).

2.6.5. *Vestibular and Ocular Motor Screening*

Vestibular impairments have been identified by researchers as a common issue that may cause delayed recovery following concussion (Hoffer, Gottshall, Moore, Balough, & Wester, 2004; Naguib et al., 2012). Additionally, visual problems during the first week of recovery have been reported by 30% of concussed athletes (Kontos et al., 2012). The concussion symptom that is associated with the vestibular and ocular motor systems is dizziness, which has been reported by 50% of concussed athletes (Kontos et al., 2012). The presence of dizziness, compared to any other on-field symptoms, is associated with 6.4 times greater predicted risk for a lengthened recovery period (>21 days) following a concussive injury (Lau, Kontos, Collins, Mucha, & Lovell, 2011). Current concussion management tools do not have specific components to assess vestibulo-ocular function; therefore, the Vestibular/Ocular Motor Screening (VOMS) was recently invented to help identify impairments and symptoms of sport-related concussion in the vestibular and ocular systems.

The VOMS assesses the vestibular and ocular motor symptoms through a series of seven tasks: smooth pursuits (H-test, eye movement with stationary head), horizontal saccades (rapid lateral eye movement with stationary head), vertical saccades (rapid up and down eye movement with stationary head), near point convergence (NPC), horizontal vestibular ocular reflex (VOR) (head rotation with eyes focused on a stationary target), vertical VOR (head nodding with eyes focused on a stationary target), and visual motion sensitivity (VMS) (standing head/trunk rotation with eyes focused on thumb held out in front of the nose). Prior to testing, a baseline self-report of current headache, dizziness, nausea, and fogginess is recorded on a scale from zero to 10. Following the completion of each VOMS task, the individual reports changes in each symptom to see if there are any severity provocations from baseline. NPC uses both the symptom report and an objective measurement in millimeters of the point of convergence. The administration of the VOMS takes about five to 10 minutes per individual (Mucha et al., 2014).

Mucha and colleagues (2014) conducted a preliminary investigation into the internal consistency and predictive validity of the VOMS and found some promising results. This study compared VOMS and PCSS scores from 64 concussed patients (5.5±4 days from injury) and 78 healthy participants who were between the ages of nine and 18 with a history of no more than one previous concussion. All VOMS components had a positive correlation with the PCSS total symptom score. The VOR and VMS were the most predictive of concussion. An NPC distance of ≥ 5 cm had a 38% increased likelihood of identifying a concussion correctly, while any VOMS item with a symptom score of ≥ 2 resulted in a 50% probability of detection. Overall, this initial exploration showed that the VOMS has internal consistency and is sensitive to identifying concussed individuals (Mucha et al., 2014). The VOMS may be a useful tool for monitoring the changes of the vestibular and ocular motor systems during concussion management, and more research on this instrument is needed to strengthen and validate these findings.

2.6.6. *King-Devick*

Another tool that has been proposed to help strengthen the sideline evaluation of concussion is the King-Devick (K-D) test. The K-D test evaluates brain function by assessing rapid eye movement and saccades (Heitger et al., 2009; Heitger, Jones, & Anderson, 2008; Galetta et al., 2011A; Oride, Marutani, Rouse, & DeLand, 1986; Maruta, Suh, Niogi, Mukheriee, & Ghajar, 2010). When completing the K-D test, individuals are instructed to read single digit numbers as fast as they can without making errors from left to right on three test cards that increase in difficulty. The test is completed twice and takes less than two minutes to administer. The number of errors and the fastest total time it takes to read all three cards constitutes the summary scores for this evaluative tool (Galetta et al., 2011A; Oride et al., 1986). In order to be used post-concussively, an individual baseline score must be available for comparison. K-D test scores have been found to be relatively stable with slight improvements with repeated testing in healthy individuals (Galetta et al., 2011A; Galetta et al., 2011B; King, Clark, & Gissane, 2012). An ICC-value of 0.97 has been reported to support sufficient test-retest reliability of the K-D test (Galetta et al., 2011B).However, more testing needs to be performed on the KD test to validate its use.

2.7. Concussion Treatment and Return to Play

When a concussive injury is suspected, the individual should immediately be removed from play and not return to participation (RTP) until cleared by a physician or trained medical profession (Giza & Hovda, 2001; Broglio et al., 2014; McCrory et al., 2013). Physical exertion and cognitive activities should be avoided during the initial recovery period following concussion until the acute symptoms resolve in order to prevent the exacerbation of symptoms (McCrory et al., 2013; Broglio et al., 2014). The consensus statement of the 4th International Conference on Concussion in Sport also agrees that the current research evidence on the effects of rest following concussion is minimal, and recommend rest during the acute phase of recovery (24-48 hours) (McCrory, 2013).

Moving into the sub-acute phase of injury, the administration of objective concussion assessments should be completed once a concussed individual is asymptomatic (McCrory et al., 2013; Broglio et al., 2014; Broglio, Macciocchi, & Ferrara, 2007; McCrea et al., 2005). Post-injury results should be compared to baseline measurements, if available, in order to determine current cognitive and motor performance deficits. Although concussion symptom resolution is used as the primary indicator for recovery, sports medicine clinicians should be aware that research has found 40% of asymptomatic individuals to still have neurocognitive dysfunctions (Broglio, Macciocchi, & Ferrara, 2007; Fazio, Lovell, Pardini, & Collins, 2007). Due to this, injured individuals should only be advanced to the next phase of recovery when they are no longer experiencing concussion-related symptoms, have a normal clinical examination, and have reached performance levels close to their baseline scores on objective concussion assessments (Broglio et al., 2014).

Before returning to athletic practices and games, a concussed individual must complete a gradual, stepwise RTP protocol (McCrory et al., 2013; Broglio et al, 2014). The steps included in the RTP protocol are: no activity, light aerobic activity (walking, stationary bike; <70% max HR), sport-specific exercises (skating, running, etc.), non-contact training drills (passing, resistance training) and full contact training (normal practice drills), and RTP (full participation in practices and games) (McCrory et al., 2013; Broglio et al., 2014). A rest period of 24-hours should occur between each step. In the event that symptoms reoccur during any stage of the RTP protocol, the patient must drop down to the last asymptomatic level and wait 24 hours until reattempting the symptom-inducing level (McCrory et al., 2013). The RTP progression can take approximately one-week to complete, but the length of time to RTP will vary depending on individual differences, the severity of concussion, and history of previous concussion (McCrory et al., 2013).   Ultimately, the management and RTP decisions following a concussion should combine a variety of objective information as well as sound clinical judgment from multiple trained sports medicine health care professionals when applicable.

A study by Majerske et al. (2008) examined the effects of post-concussion physical activity level on PCSS and neurocognitive performance on the ImPACT. A total of 95 participants were divided into self-reported physical activity treatment groups (i.e., no school or physical activity, school activity only, school and light activity at home, school and sports practice, school and sports game) and results found that those who engaged in higher activity levels performed more poorly on the visual memory and reaction time composites of the ImPACT than those who exerted less (Majerske et al., 2008). These findings suggest that engaging in high levels of physical activity following a concussion may have a negative effect on recovery.

Another study examined the effects of immediate and delayed cognitive and physical rest on concussion symptoms and ImPACT composite scores following a sports-related concussion (Moser, Glatts, & Schatz, 2012). Results found that participants (n=49) showed improved ImPACT performance and decreased concussion symptoms after a period of cognitive and physical rest regardless of when the rest period was taken during the recovery process. Although interesting, this study was done retrospectively without control subjects; therefore, it is difficult to determine if the subject improvements were a direct result of the prescribed rest period.

Another investigation by Gibson and colleagues (2013) examined whether recommended cognitive rest affects time to symptom resolution following a sports-related concussion. This study utilized a retrospective, clinic-based design that extracted data elements from medical records of previously concussed individuals. The researchers were most interested in PCSS assessments, the time to symptom resolution, and if a recommendation for cognitive rest was given to the patient. Overall, data from 135 concussed athletes was included in analyses with subjects being mostly male (72%) and having a mean age of 15±3 years. Results found that 63% (n=85) of their concussed subjects were recommended cognitive rest. Of those, 79 subjects had prolonged concussion symptoms (57 days) compared to those who were not recommended rest (29 days). When covariates were adjusted for, it was found that only the initial PCSS was associated with the duration of concussion symptoms. Additionally, there was not an association between concussion symptom resolution and the recommendation for cognitive rest. The authors concluded that there is still not enough supporting evidence for the role of cognitive rest following a sports-related concussion, and they advise clinicians to carefully consider the potential repercussions of prolonged absences from school and sport. The authors of this study also noted that they were currently working on a large scale, prospective investigation to clarify their findings on this issue (Gibson, Nigrovic, O'Brien, & Meehan, 2013).

In addition to Gibson et al. (2013), Silverberg and Iverson (2013) also acknowledged the lack of empirical data for rest following a concussion. They tackled this issue by using information from 102 research resources to compile a list of conclusions for activity resumption following injury. The authors concluded that no evidence exists that shows complete physical or cognitive rest causes improvements following a concussion, but that returning to athletic participation within the first seven-days following a concussion is associated with a higher risk of repeated injury (Silverberg & Iverson, 2013). Furthermore, vigorous exercise in the first two-weeks may delay recovery in those who have suffered more serious concussive injuries (Griesbach, Gomez-Pinilla, & Hovda, 2004; Griesbach, Hovda, & Gomez-Pinilla, 2009; Majerske et al. , 2008). The researchers also found that a graded return to physical participation is more likely to speed up recovery than to delay it (Mittenberg, Tremont, Zielinski, Fichera, & Rayls, 1996; Bell et al., 2008; De Kruijk, Leffers, Meerhoff, Rutten, & Twijmstra, 2002), and delaying the gradual return to activity beyond one-month from the time of injury may produce worst outcomes (Majerske et al., 2008). Lastly, low-level exercise below the symptom exacerbation threshold is "probably safe" and can prove beneficial after one-month post-concussion, but it is important to note that physical and cognitive effort may increase post-concussion symptoms regardless of the stage of the recovery (Griesbach, Gomez-Pinilla, & Hovda, 2004; Griesbach, Hovda, & Gomez-Pinilla, 2009; Leddy, Lambert, & Ogles, 1994; Gagnon, Swaine, & Forget, 2009).

2.8. Long-Term Effects of Concussion

The long-term effect of sports-related concussion continues to be a point of emphasis for this injury. There are studies that have examined the effects of multiple concussions and the long-lasting effects of concussion on neurocognitive function, but the findings are variable and conflicting. A number of studies have found associations between long-lasting issues and a history of concussion (Collins et al., 1999; Moser, Schatz, & Jordan, 2005; Moser & Schatz, 2002; Covassin, Stearne, & Elbin, 2008; Guskiewicz et al., 2005; Guskiewicz et al., 2007; Schatz, Moser, Covassin, & Karpf, 2011; Gaetz, Goodman, & Weinberg, 2000), while others have found no long-term effects from multiple concussions (Bruce & Echemendia, 2009; Broglio, Ferrara, Piland, & Anderson, 2006; Collie, McCrory, & Makdissi, 2006; Iverson, Brooks, Lovell, & Collins, 2006; Macciocchi, 2001).

In 2005, Guskiewicz and colleagues completed an investigation looking at the association between late-life cognitive impairments and history of cumulative concussion in retired professional football players. Researchers collected data from 2,552 retired professional football players using two self-report questionnaires focusing on general health and current cognitive abilities. Results showed that 60.8% of retired players who responded to the surveys self-reported sustaining at least one concussion during their professional career; furthermore, 24% of participants self-reported sustaining three or more concussions while playing (Guskiewicz et al., 2005). In response to a question asking if they felt that their history of concussive injury has had any permanent effect on their thinking and memory skills, 17.6% of retired football participants reported yes and that there was a negative association between the two (Guskiewicz et al., 2005).

A study by Moser, Schatz, and Jordan (2005) investigated the prolonged effects of concussion in high school athletes and found that symptom-free athletes with a history of two or more concussions had significantly lower cumulative academic grade point averages and presented with similar scores on a computerized neurocognitive baseline examination as athletes who had experienced a recent concussion (Moser, Schatz, & Jordan, 2005). Schatz, Moser, Covassin, and Karpf (2011) built off these findings and performed another study investigating prolonged symptoms in high school athletes who have a history of multiple concussive episodes. Baseline PCSS data was collected as part of pre-participation physical examinations for 2,557 high school athletes who were placed into three previous concussion history groups (none, one previous, two or more previous). Statistical analyses revealed that high school athletes with a higher number of previous concussions presented with higher severity and reoccurrence of headache, balance issues, dizziness, nausea, and fatigue than subjects with fewer or no history of concussion (Schatz et al., 2011). The findings of this study may suggest that the concussion-related cognitive difficulties observed in adults may actually begin in the adolescent years, but more research is needed to validate this finding. These two studies support the notion that concussion may potentially be effecting the overall development of cognitive function in adolescents from the point of injury.

In contrast to the studies examined above, Iverson at al. (2006) analyzed preseason ImPACT baseline tests for 867 male high school and university athletes and found that there was no association between decreased neurocognitive abilities and a history of concussion. Bruce and Echemendia (2009) found similar results in a three-part study. In part one, they examined the relationship between the performance on the computerized ImPACT and self-reported history of concussion. Part two dealt with the association between performance on traditional neurocognitive examinations and self-reported history of concussion. Part three investigated individuals who took both computerized and traditional tests and compared both sets of scores to their self-reported concussion history. Results from all three studies concluded a previous history of concussion did not have a significant impact on long-term neurocognitive performance on computerized and traditional neurocognitive examinations (Bruce & Echemendia, 2009).

There is a substantial amount of information on the short-term effects of concussion, but the true long-term effects are still questionable at this time. This is due to the current lack of prospective, objective, longitudinal data. In order to truly understand the long-term effects of concussions, studies are needed that track concussed youth athletes into their later years of life and control for the normal age-related cognitive declines. The above studies should be considered preliminary investigations. The relationship between sports-related concussions, sub concussive head impacts, and long-term cognitive health are still not well defined or understood (Broglio et al., 2014). Longitudinal research is currently being collected, so as time passes more concrete information should be available.

2.8.1. *Multiple Concussions*

Although the awareness of the general public and athletes has increased, concussions continue to occur in sport regularly. Following a single concussive injury, most athletes are able to achieve RTP status without complications. Recovery and RTP may become more challenging when an individual sustains a second, third, or fourth concussion. In fact, a history of multiple concussions may be linked to negative effects on emotional wellbeing and brain health (Omalu et al., 2005; Omalu et al., 2006; Omalu et al., 2010; McKee et al., 2009; Guskiewicz et al., 2007; Guskiewicz et al., 2005). A number of studies have investigated the issues and consequences related to multiple sports-related concussions.

Guskiewicz et al. (2003) completed a prospective NCAA concussion study examining the cumulative effects of recurrent concussion in college football athletes at 25 colleges and universities. Pre-season concussion history and Graded Symptom Checklist (GSC) baseline data was repeatedly collected for 2,905 athletes across three football seasons (1999, 2000, 2001) resulting in a total of 4,251 player-seasons. There were 196 reported concussions for 184 players in the sample, which produced an injury rate of 0.81 per 1000 AEs. The researchers found that college football players who had a history of previous concussion were more at risk for sustaining another concussive injury in the future. Specifically, results found that individuals with a previous history of three or more previous concussions were at a three times greater risk for future injury compared to individuals with no concussion history (Guskiewicz et al., 2003). It was also concluded that one in 15 football athletes who sustain a concussion may sustain another concussion in the same playing season, and that the history of a previous concussion is related to increased recovery time following recurrent concussions (Guskiewicz et al., 2003). These results add to earlier findings from an investigation on the epidemiology of concussion in collegiate and high school football players, which found that those who sustained one concussion were three times more likely to sustain a second concussion in the same season when compared to non-injured players (Guskiewicz et al., 2000).

A similar investigation by Zemper (2003) utilized a two-year prospective design to establish the relative risk of sustaining a second concussion for high school and collegiate football athletes who have sustained a concussion previously. Concussion injury data was collected by certified athletic trainers using the Athletic Injury Monitoring System (AIMS) from 56 high schools and 42 colleges during the 1997 football season, and from 33 high school and 43 colleges during the 1998 football season. Previous concussion history was established for each player based on medical documentation from the previous five-years. This study used the American Academy of Neurology (AAN) concussion severity grading scale to help diagnose a concussive injury. A total of 572 concussions occurred during the two-season data collection timeframe, which resulted in injury rates of 0.50 concussions per 1000 AEs in high school and 0.57 concussions per 1000 AEs in college football players. Relative risk results found that high school football players with a previous history of concussion had a 6.6 greater risk for sustaining a second concussion compared to high school football players who had not sustained a concussion within the past five-years. Collegiate football players with a history of concussion were at a 5.3 greater risk for sustaining a second concussion compared to collegiate football players who had not sustained a previous concussion. This led to an overall conclusion that high school and collegiate football players with a history of concussion within the previous five-years are at a 5.8 greater risk for sustaining a second concussion.

Collins et al. (2003) investigated reinjury by looking at the cumulative effects of concussion in high school athletes. Researchers divided 88 concussed high school athletes into groups of no previous concussions (n=60) and three or more previous concussions (n=28) based on self-reported history. Following a concussive episode, athletes underwent a post-concussion evaluation of on-field concussion markers (i.e., LOC, anterograde amnesia, reterograde amnesia, confusion). Results found that athletes with a history of three or more concussions prior to injury were 9.3 times more likely to present with three to four altered on-field markers than athletes with no previous history of concussion (Collins et al., 2003).

A study by Iverson et al. (2004) also found increased severity of post-concussion measures in amateur athletes who had three or more previous concussions compared to those with no history of concussion. A total of 38 high school and collegiate athletes were recruited from the University of Pittsburgh Medical Center Sports Concussion Program. All subjects underwent ImPACT baseline evaluations. Following a concussive injury, subjects were recruited and divided into two groups based upon their self-reported history of previous concussions on their baseline ImPACT. One group was comprised of those concussed athletes who had a history of three or more previous concussions and the other half of the subjects who had never sustained a previous concussion acted as matched-controls. All subjects took the ImPACT within 48-hours post-injury, and the baseline to post-injury composite score differences were compared between the two groups. At two-days post-injury, the three or more group scored significantly lower on ImPACT memory evaluations and were 7.7 times more likely to display a considerable drop in memory performance compared to the no previous history group (Iverson et al., 2004). These results indicate that there could be negative cumulative effects related to multiple concussions.

Overall, it can be concluded from the above studies that a history of concussion increases ones vulnerability to sustaining future concussive injuries and that as the number of concussions increases so does the severity of concussion clinical presentation. An explanation for the increased potential for reinjury and increased severity of symptoms following cumulative concussions could be that the cellular metabolism of the brain is already stretched to its limits and may be unable to adapt to further stresses (Giza & Hovda, 2001). When the tissue is still healing and another episode of increased ionic flux or impaired blood flow occurs, there may not be enough energy for injured tissues to recover, which results in more pronounced injury-related symptoms (Giza & Hovda, 2001).

2.8.2. *Post-Concussion Syndrome*

Post-concussion Syndrome (PCS) is defined as a vague collection of cognitive, physical, and psychological symptoms that endure for an extended period of time (≥30 days) resulting from a concussion (Broglio et al., 2014; Ruff, Camenzuli, & Mueller, 1996; Ryan & Warden, 2003; Jotwani & Harmon, 2010). It has been estimated that 15% of individuals suffering from a concussion will have at least one persistent PCS symptom (Wood, 2004). Some initial signs that may signify long-lasting concussion complication appear to be: prior head injury, increased length of LOC, longer-lasting post-traumatic amnesia, greater duration of initial symptoms, and younger age (Williams, Potter, & Ryland, 2010). The exact mechanism of PCS is unknown, but risk factors may include increasing age and female gender (Harmon et al., 2013).

The most common neurocognitive post-concussion effects are seen in the areas of memory and attention (Smits et al., 2009). Deficits in these areas are believed to result from the shearing mechanism of concussion that causes microstructural damage, but there is no evidence to confirm this hypothesis (Smits et al., 2009). Furthermore, it may be hard to identify PCS accurately due to symptom similarities with musculoskeletal injuries (Bazarian et al., 1999), depression (Iverson & Lange, 2003), pain (Smith-Seemiller, Fow, Kant, & Franzen, 2003), and whiplash syndrome (Haldorsen et al., 2003). A systematic review of the psychological treatments for concussion found an overall consensus that current concussion intervention techniques should utilize early patient education with the projection of PCS as a common occurrence following concussion to make the patient believe that nothing is out of the ordinary in the event that they do develop long-lasting symptoms, which in turn will hopefully decrease depression and anxiety effects that can exacerbate the overall severity of PCS (Snell, Surgenor, Hay-Smith, & Siegert, 2009).

2.8.3. *Second Impact Syndrome*

Second-Impact Syndrome (SIS) occurs when an individual sustains a second head impact or injury before the brain has fully healed from their initial concussion (Saunders & Harbaugh, 1984; Cantu, 1998; McCrory & Berkovic, 1998). It is characterized by profuse swelling of the brain (cerebral edema) and in most cases results in a catastrophic outcome (McCrory, Davis, & Makdissi, 2012). Beliefs about the existence of SIS are currently based on the subjective case reports without any hard evidence. In a study that investigated the 17 case-reports of SIS in current literature, it was reported that only five cases actually involved a secondary impact to the head and autopsy evidence of another structural brain injury was found for all of the remaining 11 cases (McCrory, 2001).

Overall, there is no clear evidence that SIS occurs independently from other structural brain issues and that it is solely a derivative from a second untimely head injury (Saunders & Harbaugh, 1984; Cantu, 1998; McCrory & Berkovic, 1998; McCrory, 2001; McCrory, Davis, & Makdissi, 2012). Fisher and Vaca (2004) concluded through their research done on emergency department concussion patients that a second impact causes a brain that is already suffering from cerebral edema to lose its ability to regulate intracranial and cerebral pressures, thus possibly leading to brain herniation and death within a few minutes. Although there is controversy about the existence of SIS, it is agreed that diffuse cerebral swelling is more likely to occur in concussed patients with immature brains and more conservative care is warranted in this population (Kirkwood, Yeates, & Wilson, 2006; Bruce, 1984; Snoek, Minderhoud, & Wilmink, 1984). The best way to manage SIS is to prevent it from occurring. It is imperative that an individual is free of all signs and symptoms of concussion and has successfully completed a return-to-play progression before resuming athletic contact activities.

2.8.4. *Chronic Traumatic Encephalopathy*

Chronic traumatic encephalopathy (CTE) is a progressive neurodegenerative disorder that is characterized by an increased accumulation of the tau protein within the brain that is diagnosed post-mortem (McKee et al., 2009). Signs and symptoms of CTE include: memory impairments, depression, poor impulse control, speech difficulties, personality changes, and parkinsonism (Baugh et al., 2012; McKee et al., 2009) In a 2009 study, there were 47 cases of confirmed CTE with 90% occurring in athletes (McKee et al., 2009). Since then an additional 110 cases of CTE have been identified at the Veterans Association-Boston University-Sports Legacy Institute Brain Bank (McKee

& Robinson, 2014). There are those who believe that CTE is a result from repetitive sub-concussive blows to the head over time (McKee et al., 2009; Omalu et al., 2005; Omalu et al., 2006), but this cause and effect relationship has yet to be established through research and the incidence in athletic populations is unknown. Both the CISG consensus and the NATA position statements address CTE and advise health care professionals to interpret current available evidence carefully until more longitudinal research is completed (McCrory et al., 2013; Broglio et al., 2014).

2.9. Risk-Taking Behaviors

2.9.1. *Definition and Background*

Risk-taking research focuses on volitional behaviors that are socially unacceptable in which individuals take inadequate precaution against outcomes that are likely harmful (Turner, McClure, & Pirozzo, 2004). Risk-taking is defined as the "engagement in behaviors that are associated with some probability of undesirable results" (Beyth-Marom & Fischhoff, 1997; Beyth-Marom, Austin, Fischhoff, Palmgren, & Jacobs-Quadrel, 1993; Byrnes, 2013; Furby & Beyth-Marom, 1992). A number of researchers include decision-making constructs related to goals, values, options, and outcomes in their explanation of risk-taking (Cooper, Agocha, & Sheldon, 2000; Byrnes, 2013; Zuckerman & Kuhlman, 2000; Byrnes, Miller, & Schafer, 1999; Furby & Beyth-Marom, 1992). The values of an individual and their goals determine the types of outcomes that they pursue and the options that they use to reach those desired outcomes (Byrnes, Miller, & Schafer, 1999). Risk-taking arises when the selected options could lead to more than one outcome, some of which being dangerous or having negative life consequences for the individual (Furby & Beyth-Marom, 1992). Additionally, risk-taking actions become habitual with repeated gratification, which diminishes the decision-making process to instinctual reactions rather than higher order deliberations (Zuckerman & Kuhlman, 2000).

This explanation of risk-taking is broad and may include a wide range of behaviors depending on the setting (Byrnes, Miller, & Schafer, 1999). For example, there are risks in both the academic and athletic settings, but the risk types are very different. There are intellectual and social risks in the classroom, while there are physical injury risks on a football field. The interpretation of risk-taking behaviors can also vary between individuals and the current situation (Furby & Beyth-Marom, 1992). Some may consider having unprotected sex as a high-risk activity, but those who are trying to conceive a child do not. Therefore, the subjective study of risk versus reward must be contextual in order to provide meaningful conclusions.

There are a number of perspectives on how and why risk-taking behaviors develop differently between individuals. It was traditionally thought that risky behaviors were a direct product of stable personality trait differences that were characterized by low arousal levels and the under utilization of one's behavioral inhibition system (Fowles, 1980; Zuckerman, 1983). An alternative view is that risk-taking actions are not direct derivatives of personality, but are response options that arise from the need to fulfill a number of life requirements, such as skill development, intimacy needs, and mood coping (Chassin, Presson, & Sherman, 1987; Cooper, 1994; Cooper, Shapiro, & Powers, 1998). Another idea is that individuals simply adapt risk-taking behaviors depending on their surroundings. This means that, in any given situation, a person systematically evaluates whether the potential reward is worth the risk and chooses their actions accordingly (Baumrind, 1991; Byrnes, 2013).

In order to clarify these previous theories, Cooper, Agocha, and Sheldon (2000) proposed a motivational perspective to assess the relationships between personality, affect regulatory processes, and risk-taking behaviors. A model was developed by the authors (Figure 2), which describes two distinct motivational pathways on which risky behaviors develop indirectly from personality. The first is that risk-taking behaviors are a result of enhancement motives where individuals are seeking positive affect and feelings of fulfillment. The second pathway is that risky behaviors result from coping motives in order to avoid or escape negative emotional states and situations. In this model, neuroticism (negative emotionality) steers coping motives and extraversion (positive emotionality) guides enhancement motives. Impulsivity interacts with both neuroticism and extraversion to calculate coping and enhancement motives, while also directly predicting risk-taking behaviors. The coping and enhancement motives also directly predict risky behavior outcomes. Neuroticism, extraversion, and impulsivity are core constructs of personality (John & Srivastava, 1999) and have been strongly linked to diverse risk-taking behaviors (Sher, Trull, Bartholow, & Vieth, 1999; Caspi et al., 1997) and affect regulatory processes (Tellegen, 1985; Watson & Clark, 1984).

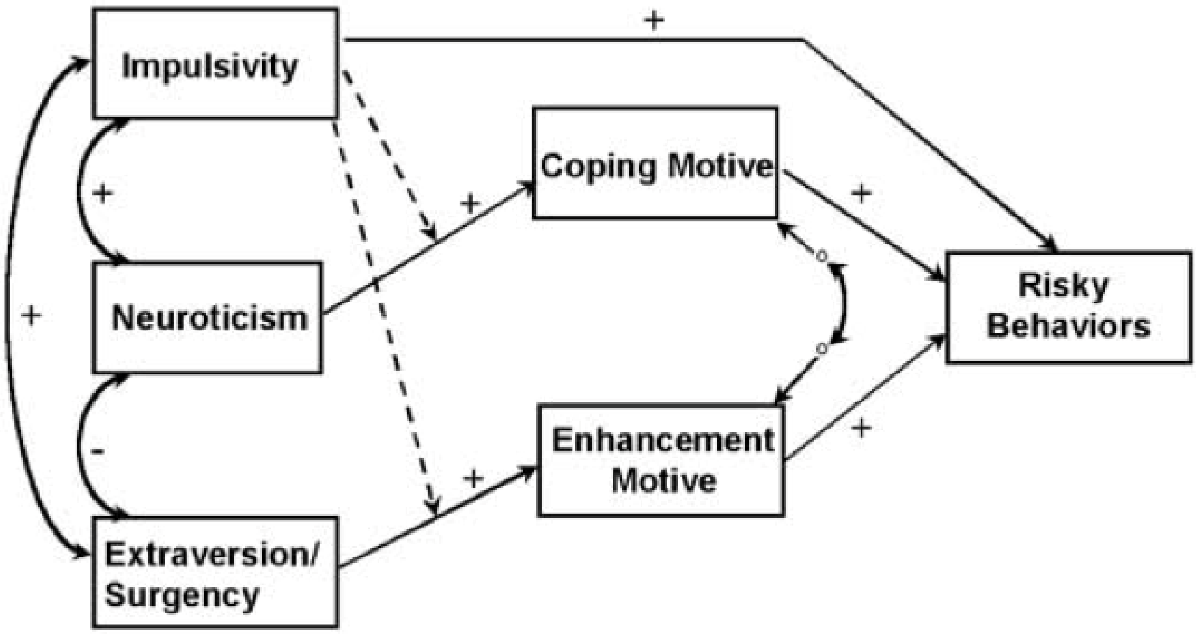


Figure 2. Model for Personality, Affect Regulation, and Risky Behaviors

From "A Motivational Perspective on Risky Behaviors: The Role of Personality and Affect Regulatory Processes" by M.L. Cooper, V.B. Agocha, and M.M. Sheldon, 2000, *Journal of Personality, 68(6),* p.1061.

Cooper, Agocha, and Sheldon (2000) tested their motivational model on two contemporary risk-taking behaviors, heavy alcohol use and risky sex. A sample of 1,666 respondents (17-26 years of age, 53% female, 50% white, 42% Black) completed face-to-face and computer-assisted interviews for this study. Neuroticism was measured using the Eysenck and Eysenck's (1987) neuroticism scale, Nolen-Hoeksema's (1991) ruminative coping style trait measure, and the Rosenberg's (1965) self-esteem scale. Extraversion was assessed by a composite of the Eysenck and Eysenck's (1987) extraversion scale, Bernstein, Hoffman, Santiago, and Diebolt's (1989) social dominance and thrill-seeking measures, and the Sensation-seeking scale by Schafer, Blanchard, and Fals-Stewart (1994). Impulsivity was quantified through an eight-item measure that assessed one's tendencies to act quickly and without forethought (adapted from Eysenck, 1967). Drinking motives, alcohol use behaviors, sex motives, and risky sexual behaviors were investigated using a variety of previously researched measurements. (Cooper, 1994; Cooper, Russell, Skinner, & Windle, 1992; Cooper, Shapiro, & Powers, 1998; Selzer, Vinokur, & Van Rooijen, 1975).

Results provided partial support for the Cooper, Agocha, and Sheldon (2000) hypothesized model. Neuroticism directly predicted coping motives as hypothesized, but it also predicted a portion of enhancement motives as well. Likewise, extraversion also predicted both motives instead of just the enhancement motives. Although neuroticism and extraversion both predicted coping and enhancement motives, neuroticism was significantly stronger at predicting coping motives and extraversion was significantly stronger at predicting enhancement motives. As expected, impulsivity indirectly predicts both motives, and directly predicted the overall outcome of risky behaviors. Contrary to what was hypothesized, neuroticism and extraversion also were directly related to predicting some of the risky behavior outcomes. These findings were small and inconsistent between drinking motives, alcohol use behaviors, sex motives, and risky sexual behaviors. Additionally, enhancement and coping motives directly predict both risky drinking and sex practices (Cooper, Agocha, & Sheldon, 2000).

From these results, a number of conclusions can be made. The development of risk-taking behaviors is complex and involves a number of direct and indirect factors. The hypothesized model is a general framework for risky behaviors, but is not a complete account for specific risk-taking actions. The relationship between personality and the development of risk-taking behaviors varies depending on the specific behavior of interest. In addition, Individuals that are neurotic are more likely to engage in risky behaviors as a way of coping with negative emotions, while extraverted individuals are more likely to engage in risky behaviors in order to increase positive emotions. Neuroticism and extraversion indirectly predict risk-taking behaviors by predicting coping and enhancement motives. The personality construct of impulsivity interacts with neuroticism and extraversion to have an indirect impact on motives, but is directly related to the actual risk-taking behavior. Overall, it appears that affect regulatory processes are an important part in the development of risk-taking behaviors even though variability exists (Cooper, Agocha, & Sheldon, 2000).

2.9.2. *Previous Research in Sport*

Literature on risk-taking and sport is limited with little information on risk-taking behaviors during actual sport participation. Some examples of risk-taking in sport could include: altering or not wearing protective equipment, intentionally performing dangerous or illegal maneuvers (i.e. spearing in football), and/or playing recklessly without concern for physical threats. It is also important to note that risk-taking behaviors in sport are viewed differently than risk-taking activities in other areas of life (i.e. gambling, sexual behaviors, driving) because they have greater social acceptability (Castanier, Le Scanff, & Woodman, 2010). For instance, when a football player violently tackles an opponent they are praised, while a reckless driver who hits another vehicle is punished. Additionally, risk-taking actions are considered context-specific and are not necessarily present across all areas of life (Lo, Repin, & Steenbarger, 2005); therefore, it should not be assumed that an individual with a gambling problem will be a risk-taking athlete on the field.

There are a number of studies that examined risk-taking in extreme sports (i.e. mountain climbing, scuba diving, hang gliding, downhill skiing). High-risk sports are defined as demanding physical activities that require specialized equipment and training to manage the risk of severe injury or death (Breivik, 1995). As described above in the personality section, there are studies that investigated risk-taking and personality in extreme sport participants. Freixanet (1991) and Tok (2011) both found that high-risk sport participants were higher in extraversion and lower in neuroticism compared to those who did not participate in extreme sports. It has also been noted that, within this population of high-risk sport participants, most people take the necessary safety measures to lessen the associated risks as much as possible, but there are some who ignore precautions and seem to adopt risk-taking behaviors intentionally (Llewellyn & Sanchez, 2008; Slanger & Rudestam, 1997).

Castanier, Scanff, and Woodman (2010) sought to explain why some people take additional risks in already high-risk sports by using a typological personality approach. The risk-taking behaviors and eight personality typologies of 302 males high-risk sport participants (downhill skiing, mountaineering, rock climbing, paragliding, and skydiving) were investigated using an objective report of previous sport accidents resulting in severe injury, a three-item risk-taking behavior scale, and the NEO-PI-R. The results found that combinations of neuroticism, extraversion, and conscientiousness were able to differentiate between high- and low-risk takers. Those high-risk sport participants who were skeptics (low neuroticism, low extraversion, high conscientiousness), brooders (high neuroticism, low extraversion, high conscientiousness), or entrepreneurs (low neuroticism, high extraversion, high conscientiousness) reported lower risk-taking behaviors. Participants in this study that were higher risk-takers were characterized by being impulsive (high neuroticism, high extraversion, low conscientiousness), hedonistic (low neuroticism, high extraversion, low conscientiousness), or insecure (high neuroticism, low extraversion, low conscientiousness) (Castanier, Scanff, & Woodman, 2010). From these studies, it can be concluded that those who are higher in extraversion and lower in neuroticism may gravitate toward high-risk extreme sports, but there are a number of different personality combinations that may characterize those who actually adopt risky sport-behaviors during participation.

Kontos (2004) completed one of the only studies dealing with risk-taking in a popular, conventional sport. The principal aim of the investigation was to determine the predictive validity of risk-taking, perceived risk, estimation of ability, overestimation of ability, and previous injuries on the occurrence of acute injury in adolescent soccer athletes. There were 260 adolescent soccer players (148 males, 112 females, mean age=12.68 years) that participated in this study. They completed a number of surveys prior to the beginning of their competitive season. Risk-taking was assessed using a nine-item Risk-Taking Behaviors Scale (RTB) that was soccer-specific and asked subjects to rank on a four-point likert scale how often they engaged in each risky soccer behavior. The Risk of Injury in Sport Scale (RISSc) was used to assess the athlete's perceived risk of injury while participating in team sports (Kontos, Feltz, & Malina, 2000). The estimation and overestimation of ability were evaluated by asking the subject and their coach to rank their own or the players "overall skill level in soccer compared to other players in their league of the same age" on a five-point likert scale with one being "very low" and five being "very high". The estimation of ability was the subject's self-report score, and the overestimation of ability was calculated by subtracting the coach's score from the subject's score. The subjects also completed a self-report of previous sport and non-sport injuries that they had sustained within the previous 12-months that warranted medical attention.

Following the initial test session, the subjects were prospectively followed for three-months during their spring soccer season. Injury information was reported by coaches three-times a week, and a follow-up phone call was made to the injured subject's parents to confirm that an injury had occurred. There were 21 subjects who sustained one injury that kept them out of their current match, forced them to sit out of the next days sport activities, or required medical attention beyond basic care. There were a number of findings for this study. It was hypothesized that risk-taking and perceived risk would be inversely related, but this was not supported by the results. Also, self-reported risk-taking was not directly related to previous injuries of sustaining an acute injury during the study period. There was a positive relationship between risk-taking and estimation of ability. Case control analyses revealed that lower levels of estimation of ability and perceived risk lead to a significant increase in injury risk. The odds ratios for sustaining the different injury types recorded for this study ranged from 3.39 to 6.10 for low estimations of ability and 3.77 to 7.92 for low perceived risk. Additionally, higher perceived risk and a high estimation of ability decreased the risk of injury (Kontos, 2004).

The results of this study conclude that high levels of self-reported risk-taking behaviors were not related to a higher incidence or risk of sustaining an injury. This study was greatly limited by its injury sample size and lack of sport diversity. This conclusion comes from only 21 soccer injuries and should not be generalized to other sports. In the future, more research is needed to investigate the relationships between risk-taking behaviors, conventional sport participation, and injury occurrence across multiple levels of competition. Overall, sport risk-taking behaviors are not well defined in the literature and it is largely unknown if there are negative consequences associated with these actions.

2.9.3. *Previous Research in Concussion and Mild Traumatic Brain Injury*

There is no previous research investigating the direct relationship between risk-taking behaviors and concussions. The consensus statement from the 4th international conference of concussion is sport (McCrory et al., 2013) does provide some introductory information on the concept of risk compensation. It is proposed that the use of protective equipment in sport provides the athlete with a false sense of security. This causes behavioral changes in play and the use of more dangerous techniques compared to if no equipment was worn. From this, there would be an increased risk of sustaining an injury (Hagel & Meeuwisse, 2004). Hedlund (2000) hypothesized that each individual has a finite threshold of risk that they are willing to accept in any given situation. By introducing protective equipment, the perceived level of risk for sport participation lowers and causes the athlete to adopt a more aggressive playing style in order to still reach the risk threshold (Hagel & Meeuwisse, 2004). The basic theory is that by applying protective equipment an individual will feel safer and will compensate for this by adopting more risk-taking behaviors during play.

Finch, McIntosh, and McCrory (2001) asked 140 rugby players (ages 14-16 years) their impressions of wearing protective headgear during sport participation. These impressions were derived from the trial use of protective headgear for the 1999 rugby season. The results found that 67% of participants who had worn headgear during the season reported that they played more confident and were able to tackle harder than when no protective equipment was worn. The researchers concluded that the introduction of protective equipment may have an influence on risk-taking behaviors in sport, but more research was needed to determine the causative relationship (Finch, McIntosh, & McCrory, 2001).

In addition to the above study, McIntosh and McCrory (2001) used the same study sample of rugby players to also complete a pilot investigation on the effectiveness of rugby headgear in reducing the incidence of concussion. They included a total of 294 rugby players that produced 1179 AE's with headgear and 357 AE's without headgear. Nine concussions occurred during the study time frame; seven in those who were wearing headgear and two in those who were not. There was no significant difference of concussion rates between the sample groups who did and did not wear headgear. Based on their pilot data, McIntosh and McCrory (2001) concluded that rugby headgear does not provide significant protection against concussions. Overall, the findings of these two studies suggest that rugby headgear does not provide injury protection and it may actual increase the use of risky-sport maneuvers; therefore, protective headgear is not warranted for rugby participants (Finch, McIntosh, & McCrory, 2001; McIntosh & McCrory, 2001). This conclusion is based on pilot data from a sample of junior level rugby players and is not generalizable to other similar sports (i.e. American football) and competition levels (i.e. youth, professional).

Risk compensation has also been investigated in ice hockey. After the use of hockey helmets was standardized in 1973, Bishop and colleagues (1983) completed a study that examined changes in the center of mass and moment of inertia related to wearing hockey helmets and face shields. No significant biomechanical changes were identified for hockey helmet and face shield use. The authors noted that they felt like the helmets gave the players a feeling of invincibility, which seemed to lead them to perform riskier maneuvers during practices and games (Bishop, Norman, Wells, Ranney, & Skleryk, 1983). Benson, Mohtadi, Rose, and Meeuwisse (1999) elaborated on this idea and investigated the incidence of head and neck injuries among ice hockey players based on the use of full versus half face shields. The researchers compared injury data for 642 university male hockey players coming from 11 teams who wore full face shields and 11 teams who wore half face shields during athletic participation. Those who wore half face shields were at a 2.31 times greater risk of sustaining a face or dental injury compared to those with full face shields, but there were no statistical differences for sustaining a concussion, neck, or other type of injury between groups. Although there was not an increased risk for sustaining a concussion between groups, those wearing a half-shield had significantly longer concussion recovery times compared to concussed athletes with full-face shields (Benson et al., 1999). The researchers believe this finding may be due to differences in helmet fit and wear between half and full face shield helmets. People wearing half shields tend to shift the helmet further back on their heads to see under the visor and subsequently expose their forehead and jaws to greater impact forces (Benson et al., 1999). Overall, the increase in protective equipment for ice hockey did not affect concussion injury rates, but may play a role in reducing concussion severity and recovery time. These findings do not support the theory of risk compensation.

The literature of risk compensation in sport is limited. At this point, it is challenging to devise a study that promotes the removal of standardized sports equipment. There is an ongoing risk compensation study that is investigating the effectiveness of a helmetless-tackling intervention in reducing the number of head impacts per athlete exposure in collegiate football (Swartz, Broglio, Cook, Cantu, Ferrara, Guskiewicz, & Myers, 2015). This study had 25 NCAA Division-I football players participate in a five-minute tackling drill without their helmets and shoulder pads and 25 match-control players who performed non-contact football drills. The Helmetless Tackling Training (HuTT) program incorporated a series of drills that emphasize proper tackling techniques at 50-75% effort. This program was completed twice a week during pre-season and then once a week during the season. The number of head impacts per athlete expose (i.e. one practice or game) was recorded using the xPatch head-impact sensor, which was attached to the mastoid process with adhesive tape prior to participation each day. Results found that the number of head impacts per one athlete-exposure significantly reduced by 28% from pre-season (13.84±7.27 head impacts) to post-season (9.99±6.10 head impacts) for the HuTT group, while the control group had no change. Additionally, the intervention group had an average of 30% fewer head impacts (9.99±6.10 head impacts) by the end of the season compared to the control group (14.32±8.45 head impacts) per athlete exposure. These findings highlight the reality of risk compensation and the importance of further researching this concept.

2.9.4. *Importance to Sport-Related Concussion*

Risk-taking behaviors during athletic participation may play a significant role in sports-related concussion occurrence, but this relationship has yet to be examined through research. Those athletes who play recklessly without concern for physical threats may be intentionally exposing themselves to concussive mechanisms. An example of this may be seen when a softball athlete sustains a concussion because she decides to dive into home plate headfirst and is forcefully struck in the helmet by the catcher's glove as she is tagged out. The concussive injury could have been avoided had she made the less risky decision to slide feet first. If a relationship exists between risk-taking and sports-related concussion, a pre-season assessment of risk-taking may be useful for injury risk identification and prevention. When an athlete is identified as a high risk-taker, then the sports medicine team could analyze their style of play and give recommendations for technique modifications for safer participation, which could potentially decreased their likelihood of sustaining a concussion. Much research is needed before risk-taking can be included as a variable for concussion prevention. The relationship between concussion and risk-taking behaviors in sport must first be established through research. Future studies should include a comprehensive variety of male and female sports from varying levels of competition and be prospective in nature in order to evaluate the causal relationship between concussion and risk-taking.

2.10. Sensation Seeking Needs

2.10.1. *Definition and Background*

Zuckerman and colleagues formally introduced the concept of sensation seeking in 1964. Sensation seeking traits are characterized by the "seeking of varied, novel, complex, and intense sensations and experiences, and the willingness to take physical, social, legal, and financial risks for the sake of such experience" (Zuckerman, 1979; Zuckerman, 1994). It is theorized that sensation seeking is a predisposition that is developed and conveyed in a variety of ways depending upon an individual's personality, social environment, and sensory experiences (Arnett, 1994). Sensation seeking is premised on the arousal theory (Zuckerman, 1969). The belief is that each individual functions best at an individualized optimal level of physiological arousal. When a person is under aroused they experience an unpleasant state of function and engage in activities that they find stimulating and/or thrilling to increase their arousal level (Eysenck, 1997). It is proposed that the purpose of sensation seeking is to increase arousal to the optimal level (Zuckerman, 1969). Therefore, high sensation seekers have a higher level of optimal arousal and need a larger variety of stimulus properties compared to those who are low sensation seekers (Zuckerman, 1979; Zuckerman & Neeb, 1980; Carrol, Zuckerman, & Vogel, 1982).

Sensation seeking is closely associated with risk-taking behaviors and much research has been devoted to defining this relationship. The results of previous investigations have found that higher levels of sensation seeking are related to dangerous driving practices (Zuckerman & Neeb, 1980; Arnett, 1990; Jonah, 1997; Arnett, 1996), alcohol abuse (Schwarz, Burkhart, & Green, 1978; Arnett, 1996), risky sexual behaviors (Zuckerman, Tushup, & Finner, 1976; Arnett, 1996), drug experimentation and use (Satinder & Black, 1984; Arnett, 1996), and criminal activity (Perez & Torrubia, 1985; Arnett, 1996). These findings have been replicated in many studies, across multiple decades, and in different countries (Zuckerman & Kuhlman, 2000). Additional research on the relationship between sensation seeking and risk-taking has found that high sensation seekers tend to subjectively evaluate dangerous situations that they have never tried before at lower risk levels and feel less anxiety compared to low sensation seekers

(Horvath & Zuckerman, 1993; Zuckerman, 1979). These low risk appraisals increase the likelihood of high sensation seekers engaging in more dangerous situations compared to low sensation seekers Zuckerman & Kuhlman, 2000). From this information, it may be concluded that individuals who are high in sensation seeking are drawn to activities that are high in risk (Hoyle, Stephenson, Palmgreen, Lorch, & Donohew, 2002).

2.10.2. *Previous Research in Sport*

There are numerous studies that have investigated sensation seeking in sport. Previous research has found evidence that athletes have higher sensation seeking needs compared to non-athletes (Schroth, 1995; Hartman & Rawson, 1992: Guszkowska & Bofdak, 2010; Ryan & Kovacic, 1966; Ryan & Foster, 1967). Schroth (1995) completed a study on the comparison of sensation seeking on different groups of athletes and non-athletes. There were 88 male (lacrosse, rugby, crew, soccer) and 64 female (soccer, volleyball, softball, tennis, golf) collegiate athletes included in this study; as well as, 70 male and 76 female college students who had never participated in organized sports. All subjects completed form V of the Zuckerman's Sensation Seeking Scale (SSS-V) (Zuckerman, Eysenck, & Eysenck, 1978). The SSS-V includes four different subscales of sensation seeking, which are: Thrill and Adventure Seeking (TAS), Experience Seeking (ES), Disinhibition (DIS), Boredom Susceptibility (BS). TAS includes items that assess the desire to participate in sports and other dangerous activities. The ES subscale focuses on assessing one's need for seeking out new or unusual experiences and sensations. DIS measures the desire for stimulating social and risqué sexual experiences. Lastly, BS measures the dislike of routine, repetition, and dull lifestyles (Zuckerman, Eysenck, & Eysenck, 1978).

The results of this study found a significant main effect that both male and female athletes had higher SSSV total, TAS, DIS, and BS scores compared to male and female non-athletes. Additionally, males had significantly higher SSS-V total, TAS, DIS, and BS scores compared to females in both the athletic and non-athletic samples. There were no significant interactions between athletic participation and sex (Schroth, 1995). These findings are similar to those previously found by Hartman and Rawson (1992) who also assessed sensation seeking differences between athletes and non-athletes. They used the SSS-form VI to primarily investigate the TAS and DIS subscales of sensation seeking for 55 male (athletes, n=29; non-athletes, n=26) and 104 female (athletes, n=27; non-athletes, n=77) subjects. Results for general male and female differences were identical to Schroth (1995) in that males had higher SSS-VI scores compared to females for both athletic and non-athletic groups. For the differences between athletes and non-athletes, Hartman and Rawson (1992) found that athletes had significantly higher SSS-VI total and DIS scores compared to non-athletes. There was also a trend that SSS TAS scores were higher for athletes compared to non-athletes, but this finding was non-significant. Overall, it can be concluded from the results of these two studies that those who participate in athletics have stronger sensation seeking needs compared to non-athletes (Schroth, 1995; Hartman & Rawson, 1992). This conclusion has also been found for high risk recreational male athletes who participate in parachuting, wakeboarding, snowboarding, scuba diving, alpinism, and/or paragliding in comparison to males who do not participate in any sporting activities (Guszkowska & Bofdak, 2010).

In addition to investigating sensation seeking differences between athletes and non-athletes, Schroth (1995) also completed analyses that looked at the difference in sensation seeking between male contact (rugby, lacrosse) and non-contact (soccer, crew) sport participants. It was found that rugby had significantly higher SSS-V total, TAS, BS, and DIS scores compared to all other sports, and lacrosse athletes scored higher on SSS-V total, TAS, BS, and DIS compared to soccer and crew athletes. Therefore, it was concluded that athletes participating in contact sports had higher sensation seeking needs compared to non-contact sports (Schroth, 1995). This finding is supported by a number of additional research investigations (Rowland, Franken, & Harrison, 1986; Jack & Ronan, 1998; Gomà i Freixanet, Martha, & Muro, 2012). Rowland, Franken, and Harrison (1986) completed an early investigation on sensation seeking and participation in sporting activities on 97 male and 104 female undergraduate students. Results found a low correlation that high SSS-V scores were related to choosing riskier sporting activities (Rowland, Franken, & Harrison, 1986). There were some factors that may have limited the results of the researchers investigation. The subjects of this study were not collegiate athletes and sport participation was based off a survey that asked participants to indicate their past and current participation and future participation interest for a list of 72 common sporting activities.

Jack and Ronan (1998) improved Rowland, Franken, and Harrison's (1986) methodology in their investigation of sensation seeking among high and low risk sport participants. For this study, high risk sports included sky-diving, mountaineering, hang-gliding, and motor-car racing, while low-risk sports were marathon running, aerobics, swimming, and golf. Scores on the SSS-V and Impulsiveness-venturesomeness-empathy scale (IVE) were collected for a total of 166 (male, n=119; female, n=47) athletes with the following sport participation: sky-diving (n=11), mountaineering (n=22), hang-gliding (n=25), motor-car racing (n=32), marathon running (n=6), aerobics (n=34), swimming (n=11), and golf (n=22). The high-risk and low-risk sport participants were categorized into low, medium, and high sensation seeking groups based upon their SSS-V total score on a range from one to 40. Low sensation seekers (n=58; 35 males, 23 females) had SSS-V total scores ranging from 4-19, medium sensation seekers (n=49) from 19-25, and high sensation seekers (n=55; 45 males, 10 females) from 26-35. Statistical analyses indicated that high sensation seekers had higher levels of impulsiveness compared to low sensation seekers, and those who participated in high-risk sports had significantly higher SSS-V scores compared to low-risk sport participants. From these findings, it can be concluded that athletes who are high sensation seekers are more impulsive and gravitate toward higher risk sports Jack & Ronan, 1998). These results are consistent with the findings from previous research (Freixanet, 1991; Rowland, Franken, & Harrison, 1986; Wagner & Houlihan, 1994; Robinson, 1985; Cronin, 1991) and a recent systematic review on sensation seeking and sport engagement (Gomà i Freixanet, Martha, & Muro, 2012).

Within the sports literature, there are also two research studies that investigate sensation seeking and injury risk. The first study by Bouter and colleagues (1988) investigated the role of sensation seeking as a risk factor for sustaining an injury in competitive downhill skiing. Sensation seeking was assessed using the SSS-V for 507 downhill skiers (290 males, 217 females). The injury group was made up of 219 (91 males, 128 females) skiers who had a history of a fracture, dislocation, or ruptured ligament during sport participation. The control group was comprised of 288 (199 males, 89 females) skiers who had never sustained a serious injury during participation. The statistical analyses revealed the injured skier group had a significantly lower SSS-V TAS scores and slightly lower SSS-V total and BS scores compared to the control group. No between group differences were found for the SSS-V ES and DIS subscale scores. These findings are opposite what was originally hypothesized. The researchers provided the possible explanation that high TAS skiers may be better at juggling the multiple physical risks associated with participation and are thus less prone to accident and injury (Bouter, Knipschild, Feij, & Volovics, 1988) . The findings of this study were limited by the retrospective administration of the SSS-V and the subjective injury self-report by the subjects.

The second study on sensation seeking and sport injury was completed more recently in 2009 by Osborn, Blanton, and Schwebel. They used the SSS-V to assess sensation seeking in 18 professional ice hockey players. The total number of injuries sustained by each participant was determined by collecting practice and game injury information from the athletic training staff for the first 18-weeks of the regular season. Descriptive statistics showed that the participants sustained an average of 5.94±4.96 injuries during the 18-week study with an average time loss of 9.61 days. Correlation analyses revealed that the total number of injuries was significantly correlated with higher SSS-V total and BS scores and also approached significance with the ES subscale. It can be concluded from this that ice hockey athletes who suffered more injuries had higher sensation seeking needs and boredom in non-stimulating situations (Osborn, Blanton, & Schwebel, 2009). These findings differed from those by Bouter and colleagues (1988), but make sense from a theoretical perspective. This study is limited by its small sample size, singular sport focus, and lack of competition level diversity.

Therefore, these findings are not generalizable and more research is needed for all sports in all levels of competition.

Overall, a few conclusions can be made from the existing literature on sensation seeking and sport. First, those who engage in sport activities have higher sensation seeking needs compared to non-athletes Schroth, 1995; Hartman & Rawson, 1992: Guszkowska & Boldak, 2010; Ryan & Kovacic, 1966; Ryan & Foster, 1967). Additionally, high sensation seeking athletes tend to gravitate toward participation in riskier sports compared to low sensation seeking athletes (Jack & Ronan, 1998;. Freixanet, 1991; Rowland et al., 1986; Wagner & Houlihan, 1994; Robinson, 1985; Cronin, 1991; Gomà i Freixanet, Martha, & Muro, 2012). Lastly, there is conflicting evidence as to whether sensation seeking has an impact on injury risk (Osborn, Blanton, & Schwebel, 2009; Bouter et al., 1988) and more research is needed to clarify and strengthen previous findings. This conclusion demonstrate the importance of identifying sensation seeking needs as they may be helpful for predicting an individuals participation in athletics and injury risk.

2.10.3. *Previous Research in Concussion and Mild Traumatic Brain Injury*

There are few previous studies that have investigated the relationship between sensation seeking and concussion or mTBIs. Hollis and colleagues (2009, 2012) completed two studies dealing with sensation seeking in rugby. The first study focused on the incidence, risk, and protective factors associated with concussions in non-professional male rugby players (Hollis et al., 2009). A total of 3,207 subjects were recruited and completed a 15-minute pre-season research questionnaire. The questionnaire was comprised of sections for demographic information, rugby playing history and equipment use, previous concussion and head injury self-report, and the SSS-V for impulsivity assessment. After the initial questionnaire, the subjects were prospectively followed over three 20-week seasons from 2005-2007. For this study a concussion was defined as any head injury event that caused the player to leave the field or the stoppage of play because of dizziness, confusion, loss of coordination, and/or loss of consciousness. A trained injury recorder, coach, doctor, or physical therapist collected all concussion data. A total of 347 concussions were recorded for 313 players during the test period with 29 of those subjects sustaining multiple concussions. The results found an overall incidence rate of 7.97 concussions per 1000 AE's. For sensation seeking, subjects who had high scores on the SSS-V (IR=9.91; 95% CI 7.40-13.01) had a significantly higher concussion incidence rate compared to low scorers (IR=7.12; 95% CI 6.00-8.39). Therefore, it can be concluded that rugby players who have high sensation seeking needs incur concussions at a greater rate compared to low sensation seeking rugby players (Hollis et al., 2009).

The second study by this research cohort (Hollis, Stevenson, McIntosh, Shoes, & Finch, 2012) investigated the compliance with concussion RTP regulations in school and community rugby union participants. The subjects were comprised on 1,958 male rugby players from suburban, grade, and schoolboy competition levels with an age range from 15 to 48 years. Each subject completed a questionnaire prior to their competitive season, which included sections on demographic information, the SSS-V for impulsivity, rugby playing experience, and the number of concussions sustained in the previous 12-months. Subjects were tracked for one season and concussive injuries were documented by coaches, doctors, or physiotherapists if a blow to the head produced a stoppage of play, the need for medical attention, or caused the player to leave the field. For three-months after a concussive injury diagnosis, the researchers followed up with subjects at five separate time intervals to collect information on injury treatment, management, recommended RTP advice that they had received, and their actual RTP behaviors. Concussed subjects were deemed “compliant” if they followed the International Rugby Board’s three-week Stand Down regulation, which states that those players who sustain a concussion must take a three-week break from training and game participation. A total of 215 concussions occurred in 10% (n=187) of the subject population. Eighty-seven percent of concussed subjects returned to participation within one-week of their injury with a median of three days rest, and 94% had returned by the end of the third week of participation removal. Results found that 78% of concussed subjects were not given the correct rugby RTP recommendation. Additionally, of those who did receive the correct RTP information, all still failed to comply with the three-week Stand Down regulation. Overall, the results found no significant association between sensation seeking scores and the concussed subjects’ compliance with the three-week Stand Down regulation. Therefore, it can be concluded that the degree of sensation seeking needs does not predict concussion RTP compliance in rugby players (Hollis et al., 2012). Both of these studies (Hollis et al., 2009; Hollis et al., 2012) were limited by their varying concussion diagnosis procedure and lack of sport and sex diversity. Future research on sensation seeking and sports-related concussion should incorporate a variety of male and female sports and include more stringent concussion identification methods.

Moving away from the sport realm, O’Jile and colleagues (2004) completed a retrospective study on sensation seeking behaviors in young adults with and without a history of previous head injury. The retrospective nature of this study is similar to the methodology that will be used for the current investigation. A total of 217 undergraduate students from a large southern university were recruited for participation in this study. Of those, 66 subjects had a previous history of a head injury, while 151 subjects did not. A head injury was defined as a self-reported head trauma that resulted in some alteration of consciousness. All subjects completed the SSS-V, Driver Risk Index, and the MacAndrews Alcoholism Scale at a single time point. The analysis of group differences found that those with a history of head injury scored significantly higher on the SSS-V TAS subscale compared to non-head injury participants (p=0.049). There was a similar trend toward significance for the SSS-V total (p=0.070) and BS (p=0.059) scores with head injury subjects attaining higher scores. From these findings, it is concluded that there is a relationship between head injury and higher sensation seeking needs (O'Jile, Ryan, Parks-Levy, Betz, & Gouvier, 2010). This study was limited by its retrospective approach, which lead the researchers to emphasize that the direction of the relationship between sensation seeking and head injury was not able to be determined. It is unclear if high sensation seeking needs contributed to sustaining a head injury or if sustaining a head injury resulted in an increased sensation seeking need. To answer this question, a prospective study is needed to determine the relationship between baseline and post-concussion sensation seeking levels. Additionally, the definition for head injury was vague for this study and based solely on the alteration of consciousness. Many times head injuries, especially those that are less severe, do not involve the alteration or LOC; therefore, this definition should be redefined and given more structured requirements for use in future research.

2.10.4. *Importance to Sport-Related Concussion*

Overall, the studies above show the need for more research on sensation seeking as it relates to concussion. In male rugby players, high sensation seekers had a higher concussion incidence rate compared to low sensation seekers (Hollis et al., 2009). Due to the lack of research, it is unknown if these findings are generalizable for all sports and female athletes. Higher sensation seeking did not predict non-compliance to the International Rugby Board's concussion RTP guidelines (Hollis et al., 2012), but it is not clear how sensation seeking may relate to other RTP procedures for different sports and organizations. Additionally, those with a history of head injury had higher sensation seeking compared to non-injured individuals in a sample of the general population (O'Jile et al., 2010). It is unclear if this finding would be similar in an athletic population for sports-related concussion.

The study of sensation seeking is important to sports-related concussions because it may be a possible predictor of concussion risk. High sensation seekers have an elevated arousal threshold compared to low sensation seekers, which drives them to pursue activities that fulfill their need for intense sensations and experiences. In general, high sensation seekers engage in riskier situations in order to reach their optimal level of arousal. From an athletic perspective, someone who is higher in sensation seeking may adopt an aggressive style of play and put themselves in more dangerous situations in order to feel the euphoria of an adrenaline rush. These riskier actions may put these individuals in a more vulnerable position to sustain a concussion compared to low sensation seeking counterparts who play with caution. If research finds that high sensation seeking male and female athletes from a variety of sports have higher concussion incidence rates compared to low sensation seeking athletes then baseline sensation seeking assessments may be warranted. A measure of individual sensation seeking needs prior to the beginning of sport participation would help clinicians identify their high sensation seeking athletes. They would then be able to provide this group with additional preventative concussion education and work with coaches to modify playing techniques in hopes of reducing concussion risk. Future prospective research is needed to clarify previous findings on the relationship between sensation seeking and sports-related concussion.

2.11. Mood States

2.11.1. *Definition and Background*

A clear definition of mood is absent in a number of frequently-cited articles dealing with this intrinsic construct (Renger, 1993; Rowley, Landers, Kyllo, & Etnier, 1995; Terry 1995). In response to this issue, Lane and Terry (2000) provided a definition for mood that describes it as "a set of feelings, ephemeral in nature, varying in intensity and duration, and usually involving more than one emotion." Mood is believed to be ever-present, but varies in intensity and duration based upon the subjective recognition of pleasant or unpleasant feelings and the degree of arousal (Parkinson, Totterdell, Briner, & Reynolds, 1996; Watson & Clark 1994; Lane & Terry, 2000). Although emotion is an important component of mood, it is important to make a distinction between the two. Researchers propose that emotions are brief, intense experiences in response to the cognitive judgment of a specific situation, while moods are prolonged, low intensity experiences that relate to individual characteristics rather than being responses to outside stimuli (Davidson & Ekman, 1994; Morris, 1992; Parkinson et al., 1996; Watson &

Clark, 1994). Moods are general feeling states, and emotions are reactions to situational factors (Parkinson et al., 1996). This distinction is practically unidentifiable as both mood and emotion are constantly adapting in order to activate the appropriate coping resources needed to manage the demands of life (Batson, Shaw, & Oleson, 1992; Brehm, 1999; Morris, 1992, Parkinson et al., 1996).

In previous literature, the study of mood is approached primarily using the six-dimension Profile of Mood States (POMS) and the two-factor Positive and Negative Affect Schedule (PANAS). The POMS has 65-items that factor down into six dimensions of mood: anger-hostility (angry, annoyed, bad-tempered, bitter), confusion-bewilderment (confused, mixed-up, muddled, uncertain), depression-dejection (depressed, downhearted, miserable, unhappy), fatigue-inertia (exhausted, sleepy, tired, worn-out), tension-anxiety (anxious, nervous, panicky, worried), vigor-activity (active, alert, energetic, lively), and friendliness (McNair, Lorr, & Droppleman, 1992). The 20-item PANAS assesses the general degree of positive and negative affect (Watson, Clark, & Tellegen, 1988). The positive affect items included in the PANAS are being enthusiastic, interested, determined, excited, inspired, alert, active, strong, proud, and attentive. Being scared, afraid, upset, distressed, jittery, nervous, ashamed, guilty, irritable, and hostile are all descriptors of the negative affect construct (Watson, Clark, & Tellegen, 1988). Although the POMS and PANAS are intrinsically different, previous research has found a relationship between the two mood scales (Terry, Lane, & Fogarty, 2003). There is a strong positive correlation between the PANAS negative effect construct and the POMS anger-hostility (0.67), confusion-bewilderment (0.80), depression-dejection (0.66), fatigue-inertia (0.58), and tension-anxiety (0.80) dimensions. Additionally, the POMS vigor-activity dimension is strongly correlated to the POMS positive affect construct (0.78) (Terry, Lane, & Fogarty, 2003).

2.11.2. *Previous Research in Sport*

The relationship between mood and sport has been extensively studied within the literature. Although there have been many different types of investigations about mood and sport, a meta-analysis by Beedie, Terry, and Lane (2000) identified three commonly investigated questions, which are: do mood responses differ between athletes and non-athletes, are there different mood responses for varying achievement levels, and can mood responses foretell performance outcomes among athletes of similar abilities? Of these questions, the first is the most relevant for the current investigation. An understanding of the differences between athletes and non-athletes would provide a normative starting point for which mood states can be compared to following a sports-related injury, such as concussion.

The early studies of mood and sport were conducted by Morgan and his colleagues in the 1970's (Morgan, 1974; Morgan & Johnson, 1978; Morgan & Pollock, 1977; Nagle, Morgan, Hellickson, Serfass, & Alexander, 1975). The main focus of these investigations was to determine if the mood states of athletes differed from those of the general population. These investigations found that those who participated in athletic activities, such as rowing and distance running, were characterized as having above average vigor and below average tension, depression, anger, fatigue, and confusion compared to population normative values. Morgan went on to term this mood combination as the "iceberg" profile and developed his Mental Health Model around the belief that positive mental health is correlated to success in sport (Morgan, 1980; 1985).

A qualitative review of the literature found that explorations by LeUnes, Haywood, and Daiss (1988), Renger (1993), and Vanden Auweele, De Cuyper, Van Mele, and Rzewnicki (1993) all confirmed the existence of the iceberg mood profile in varying athletic populations.

To further strengthen these findings, Terry and Lane (2000) completed a large-scale study to determine the normative values of the POMS for a sample of 2,086 athletes (1,244 men; 842 women) from 20 different sports at varying levels of performance (international, club, and recreation). The international sports included in this study were: alpine skiing, badminton, bobsled, canoeing, cricket, fencing, golf, hang gliding, horse racing, judo, karate, pentathlon, netball, rowing, rugby, squash, swimming, tennis, track and field, and triathlon. The club sports were comprised of badminton, basketball, boxing, canoeing, cricket, cycling, field hockey, figure skating, golf, gymnastics, ice hockey, karate, netball rowing, rugby, soccer, track and field, triathlon, and volleyball. Lastly, the recreation group included those who participated non-competitively in aerobics, alpine skiing, golf, jogging, and weight training. All subjects completed the POMS in one of three testing environments: pre-competition/exercise, post-competition/exercise, and removed from the athletic arena. The results of this study produced a number of relevant findings.

First, there were significant overall differences between this study's athletic sample and general population normative mood scores. These differences mimicked those found in previous research (Morgan, 1974; Morgan & Johnson, 1978; Morgan & Pollock, 1977; Nagle et al., 1975; LeUnes, Haywood, & Daiss , 1988; Renger, 1993; Vanden Auweele, et al.,1993) and Morgan's iceberg mood profile was distinctly seen with athletes having higher vigor and lower tension, depression, anger, fatigue, and confusion (Terry & Lane, 2000). Additionally, no significant sex differences were found for mood scores between male and female athletes (Terry & Lane, 2000). This result is harmonious with findings from Craighead, Privette, Vallianos, and Byrkit (1986), Fuchs and Zaichowsky (1983), Goss (1994), and Stratton (1996). When comparing mood during athletic situation and different levels of competition, significant variations were also noted. Mood was less positive before competition compared to after (Terry & Lane, 2000), which can be rationalized by the previous finding that impending competition is associated with elevated levels of competition anxiety (Hardy, Jones, & Gould, 1996). For the level of competition differences, international competitors had significantly higher levels of depression and anger and lower levels of fatigue and confusion compared to recreational athletes. It was also found that the club sport participants were lower in vigor and higher in tension, depression, anger, fatigue, and confusion compared to the international and recreational groups. These findings were moderate overall and may be explained by the difference in participation motives between the different groups (Terry & Lane, 2000). According to previous research, recreational athletes are drawn to participate in physical activities due to mood-enhancing motives, while club and international groups are motivated to participate in order to satisfy their competitive needs (Berger, Owen, & Man, 1993; Biddle, 1995). Overall, this study lends to the confirmation that both male and female athletes have a normative mood state which is characterized by being high in vigor and low in tension, depression, anger, fatigue, and confusion. These mood states adapt to specific athletic situations and moderately vary between the levels of participation.

Another area of interest within sport is the relationship between mood states and injury. Previous research has approached this topic in two ways. The first direction is to examine how sustaining a sports-related injury affects mood states. A study by Smith and colleagues (Smith et al., 1993) investigated the differences in pre- and post-injury mood states in competitive athletes. A total of 276 (238 males, 38 females) competitive hockey, basketball, baseball, and volleyball athletes completed a pre-season POMS assessment. The subjects were tracked throughout their competitive season and POMS reassessments were completed following sports-related injuries. At the end of the data collection period, 43 injuries had been sustained by 36 athletes. Injuries were categorized as being minor to moderate (n=27) if the athlete was removed from participation for one to two weeks and severe (n=9) if they were sidelined for more than three weeks. Pre- to post-injury mood state comparisons found that depression and anger significantly increased and vigor significantly decreased after an injury was sustained. The severity of injury was a significant predictor for post-injury depression scores (Smith et al., 1993). From these results it can be concluded that sustaining an injury causes an increase in negative and decrease in positive mood states from pre-injury levels.

Another study found a similar conclusion. Leddy, Lambert, and Ogles (1994) looked at the psychological consequences of athletic injury in collegiate athletes. The subjects for this study were collegiate male athletes (n=343) who participated in football, wrestling, basketball, track and field, gymnastics, cross-country, swimming, basketball, tennis, and golf at the division-I level. All subjects completed the Beck Depression Inventory (BDI), State-Trait Anxiety Inventory (STAI), and Tennessee Self-Concept (TSCS) scale prior to their competitive season. When an injury occurred, the injured subject and a matched control each completed the BDI, STAI, and TSCS within one week post-injury and then again at two-months post-injury. There were 30 participants who were currently injured when they completed the baseline assessments, and were consequently excluded from analysis. For the 313 athletes that remained, a total of 145 sustained injuries during the test period, which resulted in a 47.8% injury rate of the sample. The most common joint injured was the knee with 19.6% of all injuries and the most common injury was an ankle sprain (9.9%). Results found that the injured group at the one-week post-injury reassessment and two-month follow-up had significantly higher levels of depression, anxiety, and lower self-esteem compared to the non-injured controls. Additionally, 51% of the injured sample reported mild symptoms of depression post-injury and 12% had BDI scores that were higher and similar to those being clinically treated for depression. These findings correspond to those found by Smith et al. (1993) and a number of other previous investigations looking at the effects of injury on mood and emotional state (Chan & Grossman, 1988; Weiss & Troxel, 1986; Pearson & Jones, 1992). Overall, the evidence from these studies leads to the conclusion that injury produces a negative mood response that clinicians should be mindful of during the management and rehabilitation of orthopedic injuries.

The second mood-injury research approach is opposite of the first and investigates how mood state relates to sustaining a sports-related injury. Smith and colleagues also investigated this relationship in their 1993 study described above and found that pre-injury stress and mood state were not significant predictors of injury (Smith et al., 1993). This finding conflicts with a number of studies that did discovered a link between mood and injury occurrence. Lavallee and Flint (1996) investigated the relationship between injury occurrence and stress, competitive anxiety, mood state, and social support. The Sport Competition Anxiety Test (SCAT), Social Support Scale, Social Athletic Readjustment Rating Scale (SARRS), and the POMS were administered to 55 collegiate male football (n=42) and rugby (n=13) athletes. Injury data was recorded and the severity of the injuries (grade I, grade II, Grade III) was determined by the athletic training staff during the course of the competitive season. A total of 67 injuries occurred with 17 being classified as grade I severity, 11 grade II, and four grade III. An increased rate of injury was significantly related to having high competitive anxiety and high POMS tension/anxiety scores. Results also found that injury severity was significantly related to the POMS tension/anxiety, anger/hostility, and total negative mood state. Higher scores on these POMS variables resulted in a greater severity of injury. There was also a significant relationship between high depression scores and increased injury occurrence for the rugby sample. This finding was not seen for the football sample or when both sports were combined (Lavallee & Flint, 1996). The association between competitive anxiety and injury occurrence in athletes is similar to the findings from Blackwell and McCullagh (1990), Hanson, McCullagh, and Tonymon (1992), Petrie (1993), and Kolt and Kirby (1994). Kolt and Kirby (1994) found a similar result as Lavalle and Flint (1996) for the POMS tension/anxiety score in gymnastics, and also identified a relationship between decreased POMS vigor scores and an increased rate of injury.

Galambos, Terry, Moyle, and Locke (2005) continued the investigation of mood and injury in their retrospective examination of psychological predictors of injury among elite athletes. There were 845 subjects (233 female, 412 male) included in this study who participated in basketball, beach volleyball, rugby, soccer, softball, swimming, tennis, triathlon, and water polo. The subjects completed a questionnaire that included: a full medical history, injury information for incidents in the previous year, training characteristics, the Perceived Stress Scale-10, and the Brunel Mood Scale. The Brunel Mood Scale is made up of 24-items that assess anger, confusion, depression, fatigue, tension, and vigor. Of the included subjects, 67.1% reported having sustained an injury within the previous 12-months and 18.2% reported having a current injury at the time of questionnaire completion. Results found that those who were currently injured had significantly higher stress, anger, confusion, depression, fatigue, and tension compared to the healed or non-injured groups. In order to moderate for recent or current injuries, a subset of 233 athletes who did not report an injury in the previous year were selected to investigate previous orthopedic health history, mood, perceived stress, and time loss. This subset of the sample had a mean of 1.2 previous orthopedic injuries with a mean of one week of participation time loss. The results for this group found a moderate correlation between negative mood states (anger, confusion, depression, fatigue) and history of injury, perceived stress, and time lost from sport. Although this study was limited by its retrospective approach and self-reported orthopedic and health history information, the researchers concluded that a mood assessment may be a useful clinical tool for predicting injury related variables (Galambos et al., 2005).

The above studies on mood state and injuries have lead to the development of a consensus statement for sport injury risk, response, and recovery. Wiese-Bjornstal (2010) concluded that there is sufficient evidence for the relationship between pre-injury negative mood and an increased injury incidence. Additionally, it is apparent that injury results in an emotional or affective response that is characterized by mood disturbances such as anxiety, depression, anger, low vigor, fatigue, burnout, and grief (Weise-Bjornstal, 2010). Overall, athletes are typically characterized by a positive mood state of above average vigor and below average tension, depression, anger, fatigue, and confusion. Athletes who have a negative mood state normally may be at a greater risk for sustaining an injury. When an injury does occur, athletes tend to adopt a negative mood state in response to the unpleasant life event. These relationships between mood and sport should be taken into consideration when caring for and attempting to prevent athletic injury.

2.11.3. *Previous Research in Concussion and Mild Traumatic Brain Injury*

There are a number of previous studies that have investigated mood following concussion. Mainwaring and colleagues (2004) completed one of the first studies looking at the emotional reaction of collegiate athletes to sports-related concussion. Baseline POMS assessments were collected for collegiate men's basketball (n=17), women's basketball (n=18), football (n=85), men's hockey (n=26), women's hockey (n=24), women's lacrosse (n=28), men's mountain bike (n=34), women's mountain bike (n=12), men's rugby (n=49), and women's rugby (n=32) athletes. A group of healthy, physically active male (n=8) and female (n=20) undergraduate students was also recruited to act as a control group. Following a concussive event, the athlete participants completed POMS reassessments within 72-hours post-injury and then twice more with three to four days between administrations. The control group completed reassessments at a similar interval in order to determine the normal emotional fluctuations over the recovery timeframe.

A total of 16 concussed athletes, 28 controls, and 325 non-concussed athletes were included for statistical analyses. There were no differences in POMS scores between the three groups at baseline. The concussed group had significantly higher POMS depression, confusion, and total mood disturbance scores compared to the control group across all post-injury reassessment points. The concussion group also trended toward significance for increased tension, increased fatigue, and decreased vigor. Results also found that the concussed group did significantly decrease POMS depression, confusion, and total mood disturbance over time and most POMS variables were similar to baseline scores at the final reassessment time point. In conclusion, this study found that pre-injury mood state was not a risk factor for concussion and concussive injury caused significant transient mood disturbances that resolved within three weeks following injury (Mainwaring et al., 2004).

The findings of the above study were similar to those from previous studies on musculoskeletal injuries, but they were not identical. In order to define these differences more clearly, Hutchison and colleagues (2009) completed a study looking at the emotional responses to both concussion and musculoskeletal injuries. Three hundred and fifty collegiate athletes completed baseline POMS and injured athletes completed reassessments within 96 hours, 1 week and 2 weeks from the time of injury. Data from 20 athletes (12 men, 8 women) with physician-diagnosed concussions, 14 athletes (12 men, 2 women) with musculoskeletal injuries, and an additional control group of 19 healthy physically active undergraduate students (9 men, 10 women) were included in statistical analyses. A one-way ANOVA found that there were no significant differences in mood state between the concussed, musculoskeletal, and control groups at baseline (Hutchison, Mainwaring, Comper, Richards, & Bisschop, 2009). This finding replicates that of Mainwaring et al. (2004) and adds to the evidence that pre-injury mood states do not predict concussion occurrence. Hutchison and colleagues (2009) also found that there were significant mood state differences between the concussion and musculoskeletal groups post-injury. The concussion group was characterized as having elevated fatigue, decreased vigor, and an overall negative mood reaction following injury. The musculoskeletal group only showed significant increases in anger. Both the concussion and musculoskeletal injury groups also had increased depression scores immediately following their injuries that lingered throughout all post-injury reassessments, but this finding was not significant. In summary, the results of this study confirm that athletic injury causes negative mood disturbances, but concussed athletes react differently to their injury compared to those who sustain a musculoskeletal injury (Hutchison et al., 2009). These differences and their origins should be included in future research explorations of concussion and mood states.

Another group of researchers completed two studies that investigated depression and neurocognitive performance at baseline and following a sports-related concussion (Covassin, Elbin, Larson, & Kontos, 2012; Kontos, Covassin, Elbin, & Parker, 2012). Both studies used collegiate (n=837) and high school (n=779) athletes as their subjects. All participants completed baseline ImPACT, PCSS, and BDI-II assessments. For the first study looking at baseline differences, results found that those who were categorized as having severe depression based on the BDI-II had worse visual memory ImPACT scores and reported more somatic, cognitive, emotional, sleep, and total concussion symptoms compared to less depressed athlete groups (Covassin et al., 2012). The same group of high school and collegiate athletes who took baseline measurements were then tracked over a two-year time period. A total of 75 subjects (54 high school, 21 college) sustained a concussion and underwent ImPACT, PCSS, and BDI-II reassessments at two, seven, and 14 days post-injury. The results of the post-concussion study found that concussed athletes had significantly higher levels of depression at two, seven, and 14 days post-injury compared to baseline measurements. Collegiate athletes had significantly higher levels of depression at day 14 compared to high school athletes. Additionally, depression was related to slower reaction time at day seven and depression was related to lower visual memory scores on day 14 post-concussion (Kontos et al., 2012). All concussed subjects had BDI-II scores that represented having none or a minimal level of depression at baseline; therefore, depression group differences were not assessed for post-injury evaluations. From this, the researchers recommend that depression symptoms and mood assessments be included in baseline and post-injury concussion measures in order to first differentiate the presence of depression from concussion and to then help monitor the changes in these variables throughout the recovery process (Covassin et al., 2012; Kontos et al., 2012).

Yang, Peek-Asa, Covassin, and Torner (2015) also examined the relationship between baseline psychological symptoms and post-concussion depression and anxiety measurements. Baseline measurements of the Center for Epidemiological Studies Depression (CESD) scale and State-Trait Anxiety Inventory anxiety were collected for nine sports from two different NCAA division-I institutions. Over the study period of two non-consecutive years athletes from the study sample who had sustained an acute sports-related concussion were identified using the Sports Injury Monitoring System (SIMS).

When an injury occurred, the researchers collected post-injury reassessments of depression and anxiety at multiple time points until RTP status was achieved. A total of 71 concussions occurred and were included in statistical analyses. The results found that those concussed athletes who reported depression symptoms during the baseline assessment were 4.59 times more likely report depression symptoms and 3.40 times more likely to suffer from state anxiety following a concussive event compared to those concussed athletes who did not report depression symptoms at baseline (Yang et al., 2015). These findings add to those by Covassin et al. (2012) and Kontos et al. (2012) and increase the support for more comprehensive baseline neuropsychological assessments in order to identify those who are at a high risk for developing post-concussion psychological issues. Yang and colleagues (2015) propose that more thorough baseline measurements of psychological variables may help clinicians better differentiate between depression and anxiety symptoms that are normal for the concussed individual and those that have emerged as a result of their concussive injury. This study had a small sample size and more research is needed to strengthen these findings and to gain a better understanding of the relationship between sports-related concussions andFledd depression and anxiety mood states.

Another recent study by Vargas, Rabinowitz, Meyer, and Arnett (2015) sought to determine the predictors and prevalence of post-concussion depression in collegiate student-athletes. All athletes at a NCAA Division-I institution completed a 2-hour neuropsychological baseline test battery that included the Beck Depression Inventory-Fast Screen (BDI-FS), the Previous Head Injury Questionnaire (PHIQ), Wechsler Test of Adult Reading (WTAR), the ImPACT, and the PCSS. During the study timeframe, 84 athletes sustained a concussion and completed the same assessments post-injury. The majority (71%) of concussed subjects completed the post-injury measurements within five days following injury, and the rest completed the follow-up a week or more after their concussion. A control group of 44 undergraduate students also completed the test battery at two time points with an average of 6.8 weeks between assessments. Results found overall mild depression levels at all time points for all groups, and that there was not a significant difference in means between groups at baseline and post-concussion time points. Although significance was not found, more athletes reported clinically important depression symptoms after a concussion than at baseline. Only 11% of the concussed subjects reported BDI-FS scores above the clinical depression level cut-off during the baseline assessment compared to 23% of the concussed subjects following injury. Additionally, a number of predictive factors were identified for the development of depression symptoms following a concussion, such as: higher BDI-FS baseline scores, higher PCSS baseline scores, and age of introduction to organized athletics. It was also found that multi-racial athletes reported the highest levels of post-concussion depression compared to African American and White athletes (Vargas et al., 2015). Although 20% of the concussed sample increased in depression from baseline to post-injury, the researchers stressed that this may have occurred due to a number of different factors (i.e. school stress, life changes, being held out of participation) and it cannot be definitively linked to the athletes' concussions (Vargas et al., 2015). This study highlights the need for more research on psychological variables as they pertain to sports-related concussion and the importance for psychological-based treatment during the concussion healing process.

The acute effects of concussion on mood have been well documented in the literature, and the information on the long-term assessment of mood beyond the normal sports-related concussion recovery timeframe is growing. As previous discussed in the concussion section, the long-term effects of concussion are largely unknown. One of the original studies investigating the long-term effects of concussion on a mood variable was completed by Guskiewicz and colleagues (2007). This study used retrospective questionnaires to examine the relationship between recurrent concussion and the risk of developing clinical depression in retired professional football players. It was determined that there was an association between recurrent head injuries and clinical depression. Retired professional football players with a previous history of one or two sports-related concussions were 1.5 times more likely to be diagnosed with clinical depression than those with no previous history (Guskiewicz et al., 2007). Additionally, those reporting three or more previous concussions were at a 3 times greater risk for suffering from clinical depression, which lead the researchers to conclude that the prevalence of depression increases as the number of previous concussions increases (Guskiewicz et al., 2007). Although the findings from this study were interesting, there were a number of limitations that should be considered. The self-report methods that were used rely heavily on how well the retired football players could recall the concussions that they had sustained while playing. Due to the retrospective nature of this investigation a direct causal relationship cannot be inferred because there are many other life factors that were not controlled for that could lend to the development of clinical depression.

A follow-up to the Guskiewicz et al. (2007) study investigated the nine-year risk of depression diagnosis in the same population of retired professional football players

(Kerr, Marshall, Harding, & Guskiewicz, 2012). A baseline General Health Survey (GHS) was completed by 2,536 retired professional football players in 2001. The GHS collected demographic information, professional career self-reported concussion history, and questions on cardiovascular issues, musculoskeletal injuries, and neurological conditions. In 2010, the researchers sent out the same GHS to reassess health status in those that had responded nine-years previously. A total of 1,316 retired professional football players responded to the follow-up evaluation, which accounted for 62.6% of the original sample group from 2001. The subjects were blinded to the responses that they had provided during the baseline survey. Respondents were divided into a non-depressed group and a depressed group. The non-depressed group was comprised of those retired professional football players that had never been diagnosed with clinical depression. The depressed group was made up of those who had been diagnosed with clinical depression sometime between the initial baseline and the follow-up surveys. Those retired professional football players who had reported clinical depression at the time of baseline (n=138) were excluded from analyses. There were also 134 respondents who were excluded from analyses due to incomplete information on clinical depression and/or concussion history. Therefore, data from 1,044 former players were included in this study. Results found that 10.2% (n=106) of the sample reported clinical depression diagnosis during the nine-year study. Over the nine-year period, the risk of clinical depression diagnosis increased as the number of self-report concussions increased. A linear dose-response relationship was found with an increasing clinical depression diagnosis ranging from 3% of the "no concussion" group to as high as 26.8% of the "10 or more concussions" group (Kerr et al., 2012). Although this study is still limited by the health history and concussion self-reporting, the conclusions of this investigation add additional evidence to the theory that there is a causal relationship between sports-related concussions and long-term mental health issues.

A recent study by Chrisman and Richardson (2014) investigated whether the relationship between concussion and depression from the adult sample of retired professional football players would also be found in a younger population of 11-17 year-olds. Data from the large-scale 2007-2008 National Survey of Children's Health telephone survey was extracted for this study. The interviews covered a wide variety of health topics and were completed by the parents or caregivers as they pertained to their children. The variable of interest for this study was current diagnosis of depression with the predictor of interest being history of concussion. For this study, concussion was defined to the respondents as a brain injury that resulted in the brief disruption of brain functioning, which does not include brain tumors or head injuries that caused prolonged issues. Data from 36,060 youth subjects from across the United States met the inclusionary criteria for analyses. There was 3.5% of the study sample that reported that their child was currently suffering from depression. Of those that were currently depressed, 7.8% had a self-reported a history of concussion. For those that did not report current depression, only 2.6% acknowledged a history of a previous concussive episode. After controlling for confounders, results found that those with a history of concussion were at a 3.3 times greater risk for a depression diagnosis compared to those who did not report a history of concussion (Chrisman & Richardson, 2014). This study adds to the previous evidence from Guskiewicz et al. (2007) and (Kerr et al., 2012) that there is an association between concussion and depression regardless of age. This was a large-scale study that included a diverse sample, but it was still limited by the self-reported nature of the assessment. Due to the methodological limitations of this study, and those completed previously, it is not possible to make conclusions about the causative direction of the relationship between concussion and mental health issues.

2.11.4. *Importance to Sport-Related Concussion*

In general, a number of conclusions can be made from the previous literature on mood and concussions. There is some evidence that pre-injury mood state may not be a risk factor for sustaining a concussion (Mainwaring et al., 2004; Hutchison et al., 2009; Kontos et al., 2012), but further research is needed to confirm these findings. Sports-related concussions result with transient negative mood states that are separate from those seen for musculoskeletal injuries and tend to resolve back to baseline within three weeks following injury (Mainwaring et al., 2004; Hutchison et al., 2009; Kontos et al., 2012). Those who suffer from severe depression at the time of pre-concussion baseline measurements have decreased neurocognitive visual memory scores and increased PCSS somatic, cognitive, emotional, sleep, and total symptom reporting (Covassin et al., 2012). Depression at baseline also increases the reporting of depression and anxiety symptoms following a concussive event (Yang et al., 2015), which may have clinical implications when diagnosing and managing a depressed athlete with a concussion. Although short-term mood affects have been investigated in multiple studies, there is little on the long-term mood consequences from sports-related concussion. There is evidence that depression is associated with sports-related concussions (Chrisman & Richardson, 2014; Guskiewicz et al., 2007; Kerr et al., 2012), but it is unclear if other variables of mood (i.e.

anger, confusion, fatigue, vigor) are affected and if the same is true for sports-related concussion.

The study of mood is important to sports-related concussion because it is an adaptive variable that has clinical application in the diagnosis and psychological recovery of the concussed individual. Unlike personality traits that stay relatively constant, mood states change in order to cope with adverse situations, such as a sports-related concussion. Incorporating a mood assessment into the baseline and post-injury assessment protocol would allow evaluators to differentiate mood issues that were present prior to concussion from those that occur as a result of a concussion (i.e. depression). Assessments, such as the Profile of Mood States, may also be helpful to track mood adaptations throughout the recovery process and could give clinicians and researchers a better understanding of what a concussed individual is going through emotionally. This information would aid in the development of a more comprehensive acute and long-term concussion rehabilitation plan that includes a component on psychological recovery. Additionally, more information is needed to determine if there are any lingering mood effects as a direct result of concussive injuries. The study of mood could have a large impact on today's sport culture if a causative relationship were to be found between concussions and late-life mood disturbances and neurocognitive issues. In sum, prospective, longitudinal research is needed to clarify and determine the short-term and long-term effects of sports-related concussion on mood state for both sexes across multiple sports and levels of competition.

2.12. Personality Traits

2.12.1. *Definition and Background*

In general, personality psychology is the study of individual variability of thoughts, feeling, and behaviors (Robins & Donnellan, 2010). Personality is defined as " an individual's unique variation on the general evolutionary design for human nature, expressed as a developing pattern of dispositional traits, characteristic adaptations, and integrative life stories complexly and differentially situated in culture (McAdams & Pals, 2006)." These fundamental principles are used to form an integrative framework for understanding the person as a whole (McAdams & Pals, 2006). The root of personality investigations must begin by first looking at evolution and human nature in order to examine how and why characteristics develop (Buss, 1991; Pinker, 1999; Tooby & Cosmides, 1995).

When considering evolution, the study of the environment of evolutionary adaptedness (EEA) is used to formulate thoughts about the fundamental design of human beings (Buss, 1991). In order to survive, humans must adapt to the challenges of the environment that they are currently living. We are designed through the replication of genes and natural selection to engage in behaviors that optimize the ability to survive and reproduce (Hogan, 1982; McAdams & Pals, 2006). Sheldon (2004) defined species-typical universals that can be used to analyze personality. These universals were grouped into basic physical needs, innate social-cognitive mechanisms (i.e. classification of others, interpreting facial expressions), sociocultural practices (i.e. religion, clothing selection, food preparation) and psychological needs. Sheldon (2004) suggests that psychological needs are of key importance to personality development in the EEA. The evolution of personality is driven by the psychological need for autonomy, competence, and relatedness. Therefore, personality adapts to the environment in ways that allow us to maintain a sense of self, acquire skills to achieve our goals, and to form meaningful relationships with others (Sheldon, 2004). This conclusion is similar to Hogan's (1982) "getting along and getting ahead" approach in which he proposes that human nature and personality evolution is centered around behaving in ways that increase the chances of survival and reproduction within the structure of society. From this, McAdams and Pals (2006) concluded that our lives are simply individual adaptations of a general evolutionary blueprint of dispositional traits.

Dispositional traits are broad, comparable dimensions of personality that describe differences in individual adjustment styles to the social world, and help to explain general thoughts, emotions, and actions of individuals (Allport, 1937; Eysenck, 1952; McAdams & Pals, 2006). It is important to note the distinction between *states* versus *traits*. Fleeson (2001) describes *states* as being a person's thoughts, feelings, and behaviors at any given moment, while *traits* are the most common *states* that a person exhibits across many different types of situations and over a long period of time. Although there has been much person-situation debate in the history of personality psychology, traits have been found to predict behavioral trends across situations (Epstein, 1979; Moskowitz, 1990), important life outcomes (Barrick & Mount, 1991), social relationship quality (Asendorph & Wilpers, 1998), and psychological well-being (Diener, Sandvik, Pavot, & Fujita, 1992).

There is also evidence that personality traits have relatively good long-term consistency (Conley, 1985; Costa & McCrae, 1994; Roberts & DelVecchio, 2000).

Roberts and DelVecchio (2000) completed a qualitative review of longitudinal studies of personality consistency from childhood into the later years of time. A total of 124 longitudinal studies were included that encompassed personality test-retest data from 50,207 subjects. Due to varying ages and test-retest time intervals, the authors created age categories: infancy/toddler (birth to age 2.9), preschool (ages three to 5.9), middle childhood (ages six to 11.9), adolescence (ages 12 to 17.9), college years (ages 18 to 21.9), and each decade through age 73. Overall, trait consistency increased until the 50's decade age category where it peaked with an estimated population correlation of 0.74. Population estimates of trait consistency had similar correlations for college years (0.54), the 20's decade (0.60), the 30's decade (0.64), and the 40's decade (0.60). It is Roberts and DelVecchio's (2000) belief that an individual's personality will always adapt to the unforeseen experiences and demands of life, but this evolutionary process is slowed down during the middle-age years when day-to-day life is more stable and repetitive. Based on their meta-analytic findings, the authors concluded that personality was relatively consistent across the lifespan, but correlation results were not high enough to definitively conclude that no personality changes occur in adulthood (Roberts & DelVecchio, 2000).

There are many different types of dispositional traits seen in personality psychology research, which has caused confusion and fueled the person-situation debate in the past. Today, personality researchers commonly use a five-factor model to assess personality. Early pioneers of the five-factor model include Klages, Baumgarten, and Allport and Odbert (John, Naumann, & Soto, 2008). These individuals used a lexical approach to identify the natural language of personality by compiling lists of personality terms from dictionaries. The English investigation began in 1936 by Allport and Odbert who identified around 18,000 terms that “distinguished the behaviors of one human being from that of another.” (Allport & Odbert, 1936). They then developed the initial four-category classification structure for broad individual characteristics, which included the following: personality traits, temporary states, evaluative judgments of personal conduct and reputation, and physical characteristics and capacities (John, Naumann, & Soto, 2008). Cattell (1943, 1945) simplified their work into a more manageable multidimensional model, and proposed his 16 Personality Factor (16 PF) questionnaire in the 1970s (Cattell & Eber, 1972). The 16PF utilized five global factors: extraversion/introversion, high anxiety/low anxiety, tough-mindedness/receptivity, independence/accommodation, and self-control/lack of restraint (Cattell & Eber, 1972). This early work by Cattell and others eventually led Goldberg (1981) to develop of a comprehensive system for organizing basic personality tendencies, known simply as the “Big Five”.

The Big Five trait taxonomy is the most widely used assessment of personality and consists of the dimensions of neuroticism, extraversion, openness to experience, agreeableness, and conscientiousness (John, Naumann, & Soto, 2008). Neuroticism captures traits related to the tendency to become emotionally distressed and readily experience negative emotions such as sadness and anxiety (John, Naumann, & Soto, 2008). Extraversion encompasses traits related to social interactions and the experience of positive emotions. Extraverted individuals are talkative, energetic, outgoing, and upbeat (John, Naumann, & Soto, 2008). Openness captures traits related to artistic and intellectual curiosity. Highly open individuals are often interested in art and culture, and they enjoy experiencing new things. They also tend to be politically liberal (John, Naumann, & Soto, 2008). Agreeableness is the trait domain related to kindness, empathy, and close social connections. Agreeable individuals are compassionate, cooperative, and modest. They often dislike conflict. Last, conscientiousness captures traits related to self-control and achievement motivation. Highly conscientious individuals are responsible, organized, and able to channel their efforts to successfully accomplish their long-term goals (John, Naumann, Soto, & 2008). It is important to note the broadness of the Big Five dimensions as they each encompass a large number of diverse, specialized personality characteristics (John, Naumann, & Soto, 2008).

2.12.2. *Previous Research in Sport*

Sport culture is a major component of today's social lifestyle. The population of interest for this study is athletes; therefore, it may be valuable to investigate personality as it pertains to sport selection and participation in order to gain a better understanding of the population. Paunonen and Ashton (2001) studied the ability of the Big Five factors to predict a variety of life behaviors, one of those being sport participation. Following the initial investigation, Paunonen (2003) then completed a replication study on the same topic to strengthen the level of evidence. The first study used the NEO Five Factor Inventory (NEO-FFI) and the Jackson Personality Inventory to assess personality in 141 undergraduate students and found that those who reported organized sport participation were characterized by interpersonal affect, exhibition, play, endurance, energy level, achievement, gregariousness, activity, self-consciousness, warmth, and compliance (Paunonen & Ashton, 2001). In the replication study, Paunonen (2003) administered the NEO-FFI, the Revised NEO Personality Inventory, and the Five-Factor Nonverbal

Personality Questionnaire to two independent samples of university students (group one n= 276, group two n=142). Results found that high extraversion and low neuroticism were correlated with routinely exercising, while just extraversion was related to participation in organized sports (Paunonen, 2003).

A study by Tok (2011) examined the Big Five personality traits and participation in adventure/risky sports, such as: scuba diving, paragliding, rafting, rock climbing, and surfing. A total of 258 subjects participated in risky sports, while 70 subjects reported no previous experience or willingness to ever participate in a risky sport. Scores on the Five Factor Personality Inventory were compared between the two groups, and results found that risky sport participants had significantly higher levels of openness and extraversion and lower levels of neuroticism and conscientiousness compared to the nonparticipants (Tok, 2011). These results have some similarities to those found by Freixanet (1991) on subjects who engaged in high altitude hiking, scuba diving, power-boating, white water rafting, parachuting, hang gliding, motor racing, and motorcycle racing. Those engaging in high-risk sports were higher in extraversion and lower in neuroticism compared to controls (Freixanet, 1991). Although interesting, the sports that were investigated in these studies are not traditional high school and collegiate sports and conclusions should be applied loosely to our subject population of interest.

A study of more traditional sports compared the personality characteristics of athletes' competing in individual versus team sports (Nia & Besharat, 2010). The 134 subjects were made up of athletes from colleges and clubs throughout Iran who played volleyball (24.6%), basketball (19.4%), soccer (14.2%), track and field (11.2%), swimming (5.2%), futsal (5.2%), handball (4.5%), martial arts (3.7%), boxing (3.7%), wrestling (3%), gymnastics (3%), and water polo (2.2%). The researchers utilized the NEO-PI-R to measure personality and the Sociotropy-Autonomy Scale to assess preferred levels of social interactions. Results found that those who participated in individual sports had statistically higher conscientiousness and autonomy than team sport athletes. Additionally, team sport athletes were higher on agreeableness and sociotrophy measures. No differences between individual and team sports were seen for neuroticism, extraversion, and openness (Nia & Besharat, 2010). Nia and Besharat (2010) also compared their overall athletes' mean scores for the NEO-PI-R variables to non-athlete control groups from similar studies and found that their athletes were higher in extraversion and conscientious and lower in neuroticism than non-athletes. These findings mimic those found by previous researchers for athletes and other physically active populations (Rhodes, Courneya, & Bobick, 2001; Conner & Abraham, 2001; Rhodes & Smith, 2006; Tafti, Pakdaman, & Asgari, 2008; Saklofske, Austin, Rohr, & Andrews, 2007; Arai & Hisamichi, 1998; Potgieter & Venter, 1995; Yeung & Hemsley, 1997; Paunonen, 2003). Interestingly enough, these personality characteristics of traditional sport athletes were also similar for risky-sport participants who were found to be higher in extraversion and lower in neuroticism (Freixanet, 1991; Tok, 2011).

Overall, it can be concluded from these studies that individuals who are high in extraversion, high in conscientiousness, and low in neuroticism may be drawn to athletics and physical activity. Researchers have attempted to provide a partial rationale for why these personalities trait are dominant in sport. It is thought that sport is a collection of positive emotions (i.e., liveliness, optimism, high level of energy) that fuel systematic behaviors to achieve athletic goals (Magnus, Diener, Fujita, & Pavot, 1993; David, Green, Martin, & Suls, 1997), which leaves little room for negative emotions to be realized (i.e., fear, worry, hastiness, guilt) (Costa & McCrae, 1992; David et al., 1997; Robinson, Ode, Moeller, & Goetz, 2007). Positive emotions are related to extraversion, a goal-orientation is associated with conscientiousness, and negative emotions are linked to neuroticism (Costa & McCrae, 1992). Nia and Besharat (2010) also speculated that the relationship between personality and sport may be circular in nature in that high extraversion, high conscientiousness, and low neuroticism prepare the individual for athletic participation while at the same time athletic participation provides a mechanism for developing these particular characteristics.

2.12.3. *Previous Research in Concussion and Mild Traumatic Brain Injury*

There are a number of studies that have investigated personality in a variety of contexts that relate to concussions and other types of head injuries. One area that has garnered some concentration is the role of personality and clinical outcomes following concussion. Rush and colleagues (2004) were one of the first to investigate the relationship between pre-injury personality traits and the presence of post-concussion symptoms. Concussed participants (n=87) were recruited from a medical center and included if they were diagnosed with a mTBI with normal CT scans. Additionally, patients who had sustained orthopedic injuries (OI) (n=82) were also recruited for a control group. The injured participant and their significant others both completed the NEO-PI-R and the Neurobehavioral Functioning Inventory. The significant others completed the surveys as they pertained to the injured subjects. Results found that the personality traits that the significant others reported were moderately consistent with those reported by the concussed subjects. There were no differences in personality between groups. For both the concussed and OI groups, personality was a low predictor of symptoms. From this, the researchers concluded that there was no pre-injury personality characteristics that predisposed the subjects to sustain a concussion (Rush, Malec, Moessner, & Brown, 2004). This study was limited by its retrospective rating for pre-injury personality and is not generalizable to an athletic population who sustain sports-related concussions.

Garden, Sullivan, and Lange (2009) examined the relationship between personality and post-concussion syndrome (PCS)-like symptom reporting in a healthy sample. The subjects were made up of 93 healthy subjects with no history of previous head injuries or neurological disorders with 70% being between the ages of 18 and 29 years. The Post-Concussion Symptom Inventory and the Millon Clinical Multiaxial Inventory-III for adult personality were completed by all subjects. The subjects were divided into PCS-like present group (n=55) and the PCS-like absent group (n=38) based upon the number of symptoms they reported. Personality comparisons between groups found that the PCS-like present group reported significantly higher scores on the depressive, dependent, sadistic, negativistic, borderline, anxiety, somatic, and dysthymia variables compared to the PCS-like absent group. From these results, it can be conclude that personality traits are related to self-reported PCS-like symptoms in the absence of injury. Therefore, the authors speculate that these relationships may contribute to PCS reporting following a concussive injury and advise clinicians to consider individual baseline concussion symptoms scores during post-injury evaluation (Garden, Sullivan, & Lange, 2010).

Similarly, Merritt, Rabinowitz, and Arnett (2015) completed a study that examined personality factors and baseline symptom reporting in collegiate athletes. During their pre-participation physicals, 759 athletes from a variety of collegiate sports completed the PCSS and the NEO-FFI. Results showed that neuroticism and agreeableness were predictive of baseline symptom reporting. High neuroticism scores were associated with higher self-reported symptoms scores, while high agreeableness significantly predicted lower symptoms scores (Merritt, Rabinowitz, & Arnett, 2015). These findings support two conclusions. First, personality traits were predictive of baseline symptom reporting in a non-injured population, which is similar to the findings by Garden, Sullivan, and Lange (2010). Second, the post-concussion symptoms that are traditionally assessed during baseline concussion examinations are not concussion-specific and tend to be present in healthy individuals. Therefore, it is important to clinically compare pre- and post-injury symptom scores rather than just assuming that symptoms are a result of a concussive injury.

Another study took a different approach to examining non-sport-related concussion and personality. Collinson (2010) investigated the relationship of personality variables and the development of PCS. Within 72-hours of an emergency room visit and a concussion diagnosis, personality components were assessed using the State-Trait Anxiety Inventory (STAI), the NEO-FFI, the Beck Depression Inventory II (BDI-II), and Rotter's Locus of Control Scale. After the initial assessment, the researchers completed 3-month and 6-month follow-up phone calls where the patients verbally completed the Rivermead Post-Concussion Symptoms Questionnaire, STAI, BDI-II. A total of 62 concussion patients and 51 controls were used for this study. Results found that those who had sustained a concussion had a greater disposition toward neuroticism, anxiety, locus of control, and depression compared to healthy controls. It was additionally found that levels of neuroticism, depression, and anxiety were higher for prolonged PCS patients compared to recovery PCS patients at the 6-month follow-up. Overall, this study found that personality and psychological variables may play a significant part in the occurrence and recovery of PCS (Collinson, 2010).

The association between personality and sustaining a sports-related concussion is unclear and prospective research is needed to investigate this relationship. Healthy individuals do report concussion symptoms in the absence of an injury (Garden, Sullivan, & Lange, 2010; Merritt, Rabinowitz, & Arnett, 2015), but the effect of this on concussion susceptibility and recovery outcomes are largely unknown. Additionally, neuroticism, depression, and anxiety may be associated with PCS (Collinson, 2010), but the true relationship is indistinct. It is unknown if these personality and psychological variables predisposes an individual for PCS or if a concussive injury and PCS cause an individual to become more neurotic, depressed, and anxious. Overall, there is little research available on personality and SRCs.

2.12.4. *Importance to Sport-Related Concussion*

The study of personality is important to sports-related concussion for a number of reasons. First, personality differences have been found between individuals who report baseline concussion-like symptoms in the absence of an injury and those who do not report symptoms. From this, the use of a personality assessment may be able to aid sports medicine clinicians in identifying individuals who may naturally report more concussion symptoms compared to others. This information can then be taken into consideration for more accurate diagnosis and management of a potential concussion. If a distinct relationship was found between personality and baseline concussion symptom reporting, then personality assessments may be especially useful when a baseline PCSS is not available. A substantial amount of research is needed to clarify this relationship and determine if there is any clinical utility for concussion management.

Next, personality investigations may be helpful during the management of a concussion. Sports medicine clinicians could use a personality assessment to determine which traits are dominant in their concussed athlete. This knowledge could then be used to tailor the concussion management plan in order to fit the personality needs of the individual. For example, an athlete that is high in extraversion may need more social support during the concussion recovery process compared to someone who is more introverted. This personality information may also be helpful for identifying individuals who are more susceptible to developing a prolonged (>21 days) recovery following a concussion, such as those who have high neuroticism. If a clear connection between personality and a prolonged recovery were to be found, clinicians could use this information to develop recovery interventions with this relationship in mind in order to help reduce the risk of developing long-lasting concussive issues. Overall, pervious studies on personality and concussion take a retrospective approach to personality assessment and are more focused on concussions in the general population. Future investigations are needed for sports-related concussions in order to determine the true relationship between personality, concussion susceptibility, and the development of prolonged recovery.

CHAPTER 3

METHODOLOGY

3.1. Purpose

The primary purpose of this study was to investigate the differences in risk-taking behaviors, sensation seeking needs, mood states, and personality traits between collegiate student-athletes with and without a history of SRC. A secondary aim of this study was to assess if the psychological variables were predictive of SRC history in collegiate student-athletes. This chapter discusses the research design, participant selection, survey instrumentation, data collection and management, and data analysis that were used for this study.

3.2. Research Design

This investigation was a cross-sectional study of male and female collegiate student-athletes from 18 different sports. The survey acquired data on demographic information, previous SRC history, and psychological variables. The independent variables for this study were previous history of SRC (i.e. 0, 1, 2+), sex (i.e. male, female), and sport type (i.e. low-, moderate-, high-risk). The dependent variables were the psychological mean outcome measurements of personality traits (neuroticism, extraversion, openness to experience, agreeableness, conscientiousness), risk-taking behaviors (attention impulsivity, motor impulsivity, non-planning impulsivity), sensation seeking needs (experience seeking, boredom susceptibility, thrill and adventure seeking, disinhibition, total sensation seeking), and mood states (anger, confusion, depression, fatigue, tension, vigor).

3.3. Sample Population and Participant Selection

The target population for this study was collegiate student-athletes between the ages of 18 and 24 years. Participants were recruited from four colleges and universities within the state of Michigan and Pennsylvania. The sports medicine teams, made up of certified athletic trainers, at each institution acted as liaisons and connected the principal investigator to the athletic programs from their college or university. Both male and female student-athletes that play baseball, basketball, cross country, women's field hockey, football, golf, gymnastics, ice hockey, lacrosse, women's rowing, soccer, softball, swimming and diving, tennis, track and field, volleyball, water polo, and wrestling at the National Collegiate Athletic Association (NCAA) division I, II, and III levels were asked to participate in this study. Subjects were excluded from statistical analysis if they were under the age of 18, there was a self-report of an on-going SRC at the time of survey completion, they had a history of SRC within the previous three-months, they were non-NCAA sport participant, or if they reported a concussion with a mechanism not related to sports.

3.4. Instrumentation

A single survey that includes a demographic information section, a SRC history questionnaire, and a series of psychological surveys served as the instrumentation for this study. The demographic sections asked participants to provide their age, sex, height, weight, ethnicity, academic level, current GPA range, sport, sport position, and NCAA division level (see appendix B). The SRC history questionnaire asked subjects how many previous diagnosed SRC they had sustained, the date of their last diagnosed SRC, the circumstances under which each SRC occurred, and additional questions pertaining to their mental health (see appendix C).

Risk-taking was measured using the 15-item Barratt Impulsiveness Scale (BIS-15; Spinella, 2007; see appendix E). The BIS-15 was developed as a short form of the original version of the 30-item BIS (Patton, Standford, & Barratt, 1995). The BIS-15 asked participants to rate each item on a four-point Likert scale (1=rarely/never, 4=almost always) based upon the way in which they normally act and think. The main outcome measures of the BIS-15 were attention impulsivity, motor impulsivity, and non-planning impulsivity. A higher sum score for each outcome measure indicates higher impulsivity. The BIS-15 has been found to have Cronbach's alpha values of 0.79 and 0.81 in large samples of community-dwelling adults (Spinella, 2007). The BIS-15 is strongly correlated with the original BIS-30 (r=0.94, p<.001; Spinella, 2007).

Sensation seeking was determined using the Brief Sensation Seeking Scale (BSSS; see appendix G; Hoyle, Stephenson, Palmgreen, Lorch, & Donohew, 2002). The BSSS is a shortened and adapted version of the Sensation Seeking Scale-Form V (SSS-V; Zuckerman, Eysenck, & Eysenck, 1978). Rather than using forced choice items as the SSS-V does, the BSSS uses a five-point likert scale (1=strongly disagree, 5=strongly agree) that subjects used to rank how well each item described them. A "refuse to answer" option was also included as a possible response selection in order to decrease inaccurate responses. The main outcome measures for the BSSS were experience seeking, boredom susceptibility, thrill and adventure seeking, disinhibition, and total sensation seeking. The BSSS has an overall internal consistency of 0.76 (Hoyle et al., 2002). It was found to be a reliable measure of sensation seeking across sex, age, and ethnicity (Hoyle et al., 2002).

Mood states were assessed using the Brunel Mood Scale (BRUMS; see appendix F; Terry, Lane, Lane, & Keohane, 1999; Terry, Lane, & Fogarty, 2003). The BRUMS is made up of 24-items that asked participants to rank each mood descriptor on a five-point likert scale (0=not at all, 4=extremely) to indicate the extent to which they had experienced each feeling or emotion in the past few weeks. The main outcome measures for the BRUMS were the mood dimensions of anger, confusion, depression, fatigue, tension, and vigor. The BRUMS has been found to have strong internal consistency with alpha coefficients ranging from 0.75 to 0.86 (Terry, Lane, Lane, & Keohane, 1999; Terry, Lane, & Fogarty, 2003).

Personality traits were assessed using the Big Five Inventory (BFI). This study used the BFI version as described by the University of California, Berkeley Personality Lab (John, Naumann, & Soto, 2008; see appendix D). The BFI is a self-report inventory that uses 44-items to measure the personality constructs. Each item described a characteristic that the participant was asked to rank how well it applied to them on a five-point Likert scale (1=disagree strongly, 5=strongly agree). The main outcome measures for the BFI were scores for the level of neuroticism, extraversion, openness to experience, agreeableness, and conscientiousness that each individual possesses. Coefficient alpha levels for the BFI scales in a previous study ranged from 0.75 to 0.87 with an overall mean of 0.81 (John, Naumann, & Soto, 2008). Scores on the BFI scales are also strongly correlated with alternative measures of the same personality constructs with average convergent validity coefficients for the BFI as followed: 0.83 for extraversion, 0.98 for agreeableness, 0.95 for conscientiousness, 0.93 for neuroticism, 0.90 for openness, and an overall mean of 0.95 (John, Naumann, & Soto, 2008).

3.5. Data Collection and Management

Institutional Review Board approval was obtained from Michigan State University prior to the start of data collection (see appendix H). This study was given exempt status, as it did not collect identifiable information and posed little to no risk to its participants. Following approval, an informative e-mail for institution recruitment was sent to a total of 30 head athletic trainers who coordinate the sports medicine care for their institutions' athletic programs. Four institutions agreed to participate. The principal investigator then worked with each sports medicine team to determine the most effective way to administer the study survey at each institution. The survey was available in both paper and pencil and electronic forms. Each participating institution chose the data collection method that worked best for the needs of their athletic program. The electronic survey was constructed using the Qualtrics online survey software.

The actual data collection process consisted of subjects voluntarily agreeing to participate by completing the 10-minute single-time survey. The method of data collection varied at each institution. At three institutions the survey was completed via paper and pencil or iPad during their pre-participation physical examinations. One institution did not have formal pre-participation physical examinations, so paper and pencil surveys were distributed at a pre-season team meeting or following a fall season practice. Data collection occurred towards the beginning of the fall season before acute concussions and musculoskeletal injuries are sustained by the subject sample. Data was collected from the beginning of August until mid-September.

3.6. Data Analysis

General descriptive and frequency statistics were completed for all demographic information, SRC history, and sport information in order to gain a better understanding of the collegiate student-athlete sample used for this study. Sport was also broken down into sport types of low-risk (golf, cross country, track and field, swimming and diving, tennis, baseball, softball, waterpolo, women's rowing), moderate-risk (lacrosse, soccer, volleyball, women's basketball, women's field hockey), and high-risk (football, wrestling, ice hockey, gymnastics, men's basketball) based upon the NATA recommendations and guidelines for appropriate medical coverage of intercollegiate athletics (NATA, 2007). Additionally, Analysis of Variance (ANOVA) and Tukey's Post-Hoc tests were also completed to asess for differences in age, height, weight, and level of education between the SRC groups.

The first hypothesis that collegiate student-athletes with a history of SRC (i.e., 1 or 2+) would have higher risk-taking behaviors than those who had not sustained a SRC was tested using a series of Analysis of Covariance (ANCOVA) tests. The ANCOVAs determined the mean differences between the 0, 1, and 2+ SRC history groups for the BIS-15 main outcome measures of non-planning impulsivity, motor impulsivity, attentional impulsivity, and an overall total impulsivity score. The covariates for this analysis were sex and sport type.

The second hypothesis that collegiate student-athletes with a history of SRC (i.e., 1 or 2+) would have higher sensation seeking needs than those who have not sustained a SRC was assessed using a series of ANCOVAs. The ANCOVAs determined the mean differences between the 0, 1, and 2+ SRC history groups for the BSSS main outcome measures of boredom susceptibility, disinhibition, experience seeking, thrill and adventure seeking, and an overall total sensation seeking score. The covariates for this analysis were sex and sport type.

The final hypothesis that collegiate student-athletes with a history of SRC (i.e., 1 or 2+) will have higher mood states than those who have not sustained a SRC was analyzed using a series of ANCOVAs. The ANCOVAs determined mean differences between the 0, 1, and 2+ SRC history groups for the BRUMS main outcomes measures of anger, confusion, depression, fatigue, tension, and vigor. The covariates for this analysis were sex and sport type.

The first research question of personality trait differences between collegiate student-athletes with and without a history SRC was also explored using a series of ANCOVAs. The ANCOVAs determined mean differences between the 0, 1, and 2+ SRC history groups for the BFI main personality outcomes of neuroticism, extraversion, openness to experience, agreeableness, and conscientiousness. The covariates for this analysis were sex and sport type.

All significant ANCOVA findings were further investigated by completing ANOVA and Tukey's Post-Hoc tests. Any significant covariates that were identified, in addition to significant SRC group differences, in the ANCOVAs were also further examined by isolating each group (i.e. males versus females) and completing ANOVA and Tukey's Post-Hoc tests. Additionally, effect sizes were calculated for the mean differences between the 0 and 1 SRC groups, 0 and 2+ SRC groups, and 1 and 2+ SRC groups. The effect sizes were defined by Cohen's recommendations of 0.20 or less as a small effect, around 0.50 as a medium effect, and 0.80 or greater as a large effect (Cohen, 1988). Due to the ordinal nature of the psychological assessments, large effect size standard deviations were expected.

The second research question interested in determining if the psychological variables predicted SRC history was answered using a multinomial linear regression model. The multinomial linear regression determined what personality, risk-taking, sensation seeking, and/or mood variables predicted a history of 1 or 2+ previous SRCs relative to the student-athletes without a history of SRC. The following variables were included in the regression analysis: neuroticism, extraversion, openness to experience, agreeableness, conscientiousness, attention impulsivity, motor impulsivity, non-planning impulsivity, experience seeking, boredom susceptibility, thrill and adventure seeking, disinhibition, total sensation seeking, anger, confusion, depression, fatigue, tension, vigor, sex, and sport type. The statistical significance level was set at $p < .05$ for all analyses, and all data was analyzed using the Statistical Package for the Social Sciences (SPSS) 20.0 software.

CHAPTER 4

RESULTS

4.1. Subject Demographics

A total of 1,398 (68%) of 2,055 collegiate student-athletes targeted for this study voluntarily completed the survey.A total of 146 participants were excluded because they were younger than 18 years of age (n=18), had a current SRC (n=3), had sustained a sport-related concussion within the past three months (n=8), were currently suffering from a musculoskeletal injury (n=61), were not NCAA collegiate student-athletes (n=18; cheerleading, men's rowing), or reported concussions that were not sport-related (n=33). Additionally, five participants completed the demographic information section of the survey, but did not complete enough items in the psychological assessments to be usable for statistical analyses. Therefore, 1,252 subjects were included for statistical analyses. The SRC independent variable groups were as follows: 938 (74.9%) participants with no previous history of SRC, 205 (16.4%) participants who had sustained one previous SRC, and 109 (8.7%) participants who had sustained two or more previous SRCs. The 1 and 2+ SRC groups collectively reported an average of 3.55±2.6 years since their last concussion. Of the 109 participants who were included in the 2+ SRC group, 23 reported that they had sustained 3 previous SRC, 6 reported that they had sustained 4 previous SRCs, and 6 reported a history of 5+ SRCs. The number of participants included in analyses surpassed the a-priori power analysis target sample size of 450 subjects (d=0.30, power=0.85) that was calculated using previous research on the sensation seeking main outcome measures.

The sample included 706 (56.4%) male and 546 (43.6%) female NCAA Division-I (n=327, 26.1%), -II (n=778, 62.1%), and -III (n=147, 11.7%) collegiate student athletes. Participants had an average age of 19.5±1.3 years, height of 176.0±19.3 cm, and weight of 77.7±17.5 kg. The majority of the participants reported that they were white (n=1036, 82.7%) followed by black (n=113, 9.0%) and hispanic/latino (n=37, 3.0%). The top three male sports represented in the total sample were football (n=163, 13.0%), baseball (n=80, 6.4%), and soccer (n=75, 6.0%). The top three female sports represented in the sample were soccer (n=64, 5.1%), swimming and diving (n=61, 4.9%), and rowing (n=57, 4.6%). The distribution of participants into sport type was 44.4% (n=556) low-risk, 29.0% (n=363) moderate-risk, 26.5% (n=332) high-risk. For a complete breakdown of personal and sport demographic information by previous SRC groups see Tables 1 and 2.

The ANOVA and Tukey's Post-Hoc analyses on age, height, weight, and level of education did reveal some significant differences between the SRC groups. The 0 SRC group was significantly younger than the 1 SRC group by approximately 3 months (MD=-0.24, p=0.05), as well as the 2+ SRC group by about 4 months (MD=0.32,p=0.04). There were no significant height differences between any of the SRC groups (p=0.50). The 1 SRC group weighed significantly more than the 0 SRC group by 3.8 kgs (p=0.01), but no other weight differences were found. Lastly, there were no significant differences in education level between the SRC groups (p=0.32).

Table 1. Participant Personal Demographics

	Previous Sport-Related Concussion Groups						Total	
	0 (N=938)		1 (N=205)		2+ (N=109)		(N=1252)	
Sex								
Male	519	(55.3%)	125	(61.0%)	62	(56.9%)	706	(56.4%)
Female	419	(44.7%)	80	(39.0%)	47	(43.1%)	546	(43.6%)
Age	19.5±1.3 yrs		19.7±1.3 yrs		19.8±1.4 yrs		19.5±1.3 yrs	
Height	176.8±10.2 cm		177.8±10.7 cm		177.0±10.7 cm		176.0±19.3 cm	
Weight	76.8±16.9 kg		80.6±19.4 kg		79.4±18.6 kg		77.7±17.5 kg	
Ethnicity								
White	774	(82.5%)	168	(82.0%)	94	(86.2%)	1036	(82.7%)
Black	88	(9.4%)	22	(10.7%)	3	(2.7%)	113	(9.0%)
Hispanic/Latino	28	(2.9%)	5	(2.4%)	4	(3.7%)	37	(3.0%)
Asian	8	(0.9%)	-		-		8	(0.6%)
American Indian	3	(0.3%)	-		1	(0.9%)	4	(0.3%)
Mixed Race	31	(3.3%)	9	(4.4%)	5	(4.6%)	45	(3.6%)
Other	6	(0.6%)	1	(0.5%)	2	(1.8%)	9	(0.7%)
Year in College								
1st	297	(31.7%)	51	(24.9%)	24	(11.5%)	372	(29.7%)
2nd	249	(26.5%)	47	(22.9%)	21	(19.3%)	317	(25.3%)
3rd	200	(21.3%)	48	(23.4%)	29	(26.6%)	277	(22.1%)
4th	163	(17.4%)	47	(22.9%)	26	(23.9%)	236	(18.8%)
5th	21	(2.2%)	9	(4.4%)	7	(6.4%)	37	(3.0%)
Graduate	6	(0.6%)	3	(1.5%)	1	(0.9%)	10	(0.8%)
Unreported	2	(0.2%)	-		1	(0.9%)	3	(0.2%)

% of SRC group

Table 2. Participant Sport Demographics

	Previous SRC Groups						Total	
	0 (N=938)		1 (N=205)		2+ (N=109)		Total (N=1252)	
NCAA Level								
I	263	(28.0%)	50	(24.4%)	14	(12.8%)	327	(26.1%)
II	574	(61.2%)	123	(60%)	81	(74.3%)	778	(62.1%)
III	101	(10.8%)	32	(15.6%)	14	(12.8%)	147	(11.7%)
Sport Type								
Low-risk	465	(49.5%)	65	(31.7%)	27	(24.8%)	556	(44.4%)
Moderate-risk	240	(25.6%)	73	(35.6%)	50	(45.9%)	363	(29.0%)
High-risk	233	(24.8%)	67	(32.7%)	32	(29.4%)	332	(26.5%)
Male Sports								
Football	107	(11.4%)	37	(18.0%)	19	(17.4%)	163	(13.0%)
Wrestling	48	(5.1%)	6	(2.9%)	5	(4.6%)	59	(4.7%)
Baseball	60	(6.4%)	14	(6.8%)	6	(5.5%)	80	(6.4%)
Soccer	53	(5.7%)	14	(6.8%)	8	(7.3%)	75	(6.0%)
Basketball	43	(4.6%)	10	(4.9%)	3	(2.8%)	56	(4.5%)
Golf	24	(2.6%)	2	(1.0%)	2	(1.8%)	28	(2.2%)
Cross Country	27	(2.8%)	2	(1.0%)	-		28	(2.2%)
Track & Field	31	(3.3%)	10	(4.9%)	4	(2.0%)	45	(3.6%)
Tennis	18	(2.0%)	-		-		18	(1.4%)
Water Polo	20	(2.1%)	2	(1.0%)	-		22	(1.8%)
Lacrosse	29	(3.1%)	17	(8.3%)	15	(7.3%)	61	(4.9%)
Ice Hockey	20	(2.1%)	5	(2.4%)	1	(0.9%)	26	(2.1%)
Swim & Dive	36	(3.8%)	6	(2.9%)	-		42	(3.4%)
Female Sports								
Softball	27	(2.9%)	6	(2.9%)	3	(2.8%)	36	(2.9%)
Soccer	40	(4.3%)	18	(8.8%)	6	(5.5%)	64	(5.1%)
Basketball	28	(3.0%)	1	(0.5%)	6	(5.5%)	35	(2.8%)
Volleyball	42	(4.5%)	9	(4.4%)	1	(0.9%)	52	(4.2%)
Golf	5	(0.5%)	2	(1.0%)	1	(0.9%)	8	(0.6%)
Cross Country	35	(3.7%)	1	(0.5%)	2	(1.8%)	38	(3.0%)
Track & Field	44	(4.7%)	4	(1.6%)	2	(1.8%)	50	(4.0%)
Tennis	26	(2.8%)	-		-		26	(2.1%)
Water Polo	11	(1.2%)	4	(1.6%)	2	(1.8%)	17	(1.4%)
Lacrosse	30	(3.2%)	9	(4.4%)	11	(10.1%)	50	(4.0%)
Ice Hockey	8	(0.9%)	8	(3.9%)	4	(3.7%)	20	(1.6%)
Gymnastics	7	(0.7%)	1	(0.5%)	-	(%)	8	(0.6%)
Swim & Dive	58	(6.2%)	1	(0.5%)	2	(1.8%)	61	(4.9%)
Rowing	43	(4.6%)	11	(5.4%)	3	(2.8%)	57	(4.6%)
Field Hockey	18	(1.9%)	6	(2.9%)	4	(3.7%)	28	(2.2%)

% of SRC group

4.2. Risk-Taking Behaviors

H1: Collegiate student-athletes with a history of SRC (i.e., 1 and 2+ SRCs) will have higher risk-taking behaviors than those who have not sustained a concussion.

The hypothesis for risk-taking behaviors was partially supported. Results indicated significant differences between previous SRC groups for the Barratt Impulsiveness Scale attention impulsivity [$F_{(1,226)}=7.35$, $p=0.00$], motor impulsivity [$F_{(1,226)}=6.97$, $p=0.00$], and total impulsivity [$F_{(1,227)}=7.15$, $p=0.00$] variables. No significant differences were found between previous SRC groups for the BIS non-planning impulsivity [$F_{(1,227)}=0.92$, $p=0.40$] variable. For the BIS attention impulsivity variable, Tukey post-hoc analyses found that the 2+ SRC group had significantly higher mean scores than the 0 SRC (mean difference (MD)=0.24, $p=0.00$, $d=0.42$) and the 1 SRC groups (MD=0.18,$p=0.02$, $d=0.31$). For the BIS motor impulsivity variable, the 2+ SRC group had significantly higher mean scores than the 0 SRC (MD= 0.23, $p=0.00$, $d=0.41$) and the 1 SRC groups (MD = 0.20, $p=0.01$, $d=0.35$). Lastly, the BIS total impulsivity mean score was significantly higher for the 2+ SRC than the 0 SRC (MD=0.18, $p=0.00$, $d=0.41$) and 1 SRC groups (MD=0.15, $p=0.02$, $d=0.33$) (see Table 3, Figures 3-6).

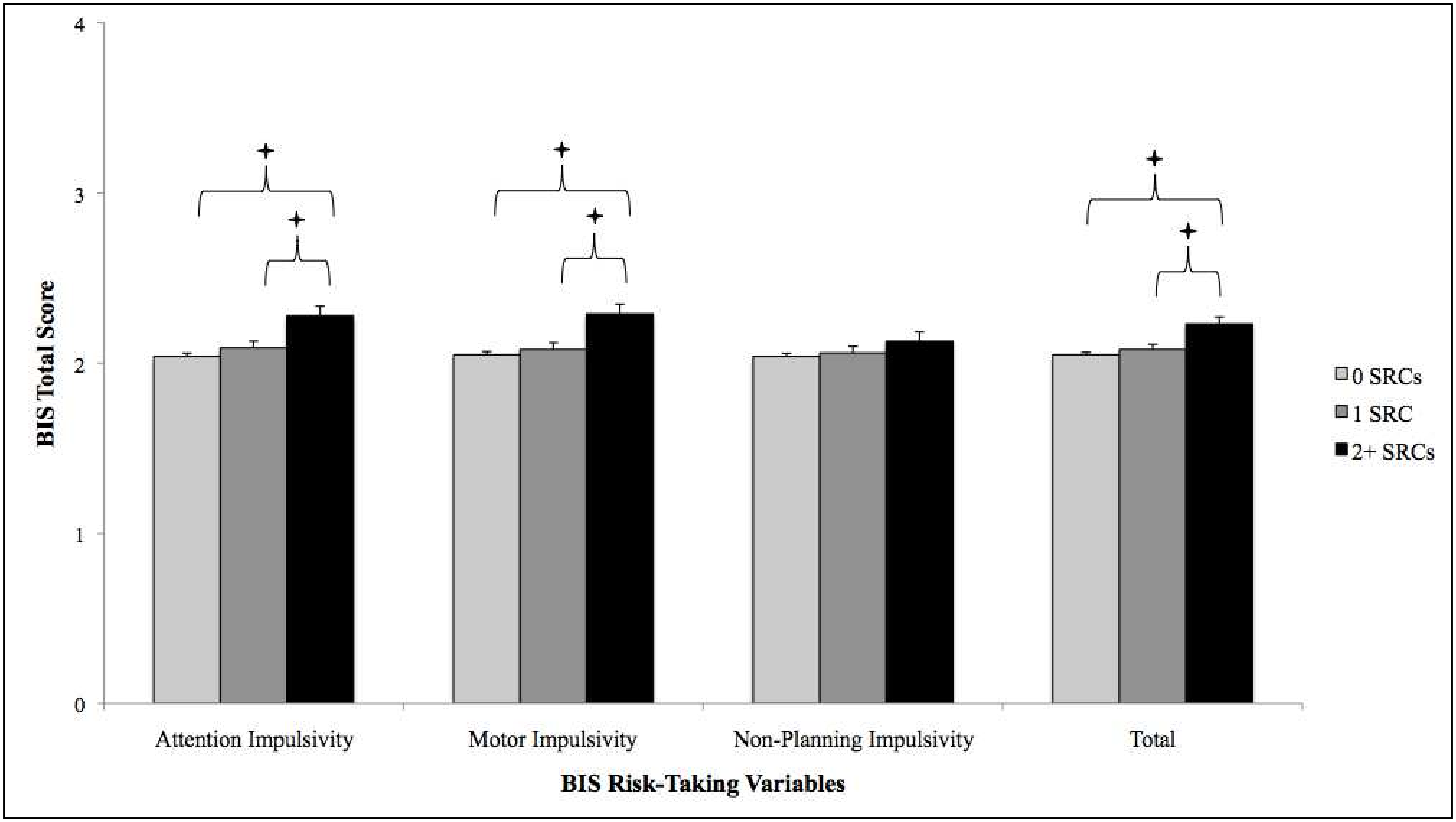
Additionally, the ANCOVA analyses also revealed that sex was a significant covariate for the BIS motor impulsivity [$F_{(1,226)}=6.86$, $p=0.01$] and total impulsivity [$F_{(1,227)}=12.16$, $p=0.00$] variables. When isolating the male participants, there were significant differences between previous SRC for the BIS motor impulsivity [$F_{(690)}=4.27$, $p=0.01$], but not for total impulsivity [$F_{(690)}=2.70$, $p=0.06$]. Tukey post-hoc analyses found significantly higher mean scores for the 2+ SRC groups compared to the 0 SRC (MD=0.21, $p=0.02$) and 1 SRC groups (MD=0.24, $p=0.02$) for BIS motor impulsivity. When isolating the female participants, there were significant differences between previous SRC groups for motor impulsivity [$F_{(533)}=4.16$,

p=0.02], and total impulsivity [$F_{(534)}$=5.54, p=0.00]. Tukey post-hoc analyses found significantly higher mean scores for the 2+ SRC group compared to the 0 SRC group for the BIS motor impulsivity (MD=0.25, p=0.02) and total impulsivity (MD=0.24, p=0.00) variables.

Table 3. SRC Group Psychological Variable Means and Effect Size Comparisons

	Previous SRC Group (mean±SD)			Effect Size (d±CI_{95})		
	0	1	2+	(0,1)	(0,2+)	(1,2+)
Risk-Taking						
Attention Impulsivity	2.04±0.56	2.09±0.62	2.28±0.61	0.09±0.15	0.42±0.20	0.31±0.23
Motor Impulsivity	2.05±0.58	2.08±0.55	2.29±0.69	0.05±0.15	0.41±0.21	0.35±0.24
Non-Planning Impulsivity	2.04±0.56	2.06±0.57	2.13±0.56	0.04±0.15	0.16±0.20	0.12±0.23
Total	2.05±0.43	2.08±0.44	2.23±0.48	0.07±0.15	0.41±0.20	0.33±0.24
Sensation Seeking						
Experience Seeking	3.66±0.94	3.65±0.95	3.84±0.99	-0.01±0.15	0.19±0.20	0.20±0.23
Boredom Susceptibility	3.48±0.81	3.52±0.83	3.67±0.77	0.05±0.15	0.24±0.20	0.19±0.23
Adventure Seeking	3.21±1.07	3.42±1.03	3.40±0.97	0.20±0.15	0.18±0.20	-0.02±0.24
Disinhibition	2.91±1.01	3.03±1.03	3.06±0.94	0.12±0.15	0.15±0.20	0.03±0.24
Total	3.32±0.71	3.41±0.71	3.50±0.68	0.13±0.15	0.25±0.21	0.13±0.23
Mood State						
Anger	1.66±0.66	1.70±0.75	1.68±0.76	0.06±0.15	0.03±0.20	-0.03±0.23
Confusion	1.75±0.69	1.69±0.74	1.72±0.73	-0.09±0.15	-0.04±0.21	-0.04±0.24
Depression	1.42±0.63	1.43±0.65	1.50±0.70	0.02±0.15	0.13±0.20	0.10±0.24
Fatigue	2.42±0.92	2.47±0.98	2.39±1.00	0.08±0.15	-0.04±0.20	-0.12±0.23
Tension	2.15±0.90	2.06±0.89	2.10±0.97	-0.08±0.15	-0.06±0.20	0.02±0.23
Vigor	3.57±0.77	3.60±0.73	3.62±0.75	0.03±0.15	0.03±0.20	0.00±0.23
Personality Trait						
Extraversion	3.52±0.69	3.57±0.69	3.65±0.61	0.07±0.15	0.19±0.20	0.12±0.23
Conscientiousness	3.81±0.58	3.81±0.56	3.74±0.47	0.00±0.15	-0.12±0.20	-0.13±0.24
Neuroticism	2.59±0.66	2.51±0.64	2.65±0.62	-0.12±0.15	0.09±0.20	0.22±0.24
Openness	3.38±0.50	3.41±0.54	3.41±0.56	0.06±0.15	0.06±0.20	0.00±0.23
Agreeableness	3.95±0.55	3.93±0.53	3.94±0.52	-0.04±0.16	-0.02±0.20	0.02±0.23

Figure 3. Risk-Taking Differences Between Previous SRC Groups



+ $p<0.05$

Figure 4. Risk-Taking Effect Sizes Between 0 and 1 Previous SRC Groups

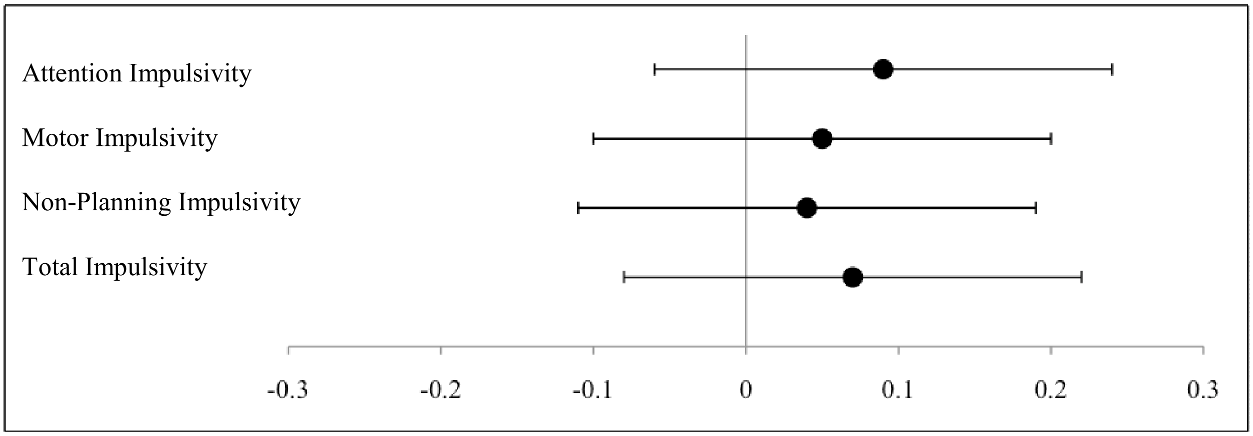


Figure 5. Risk-Taking Effect Sizes Between 0 and 2+ Previous SRC Groups

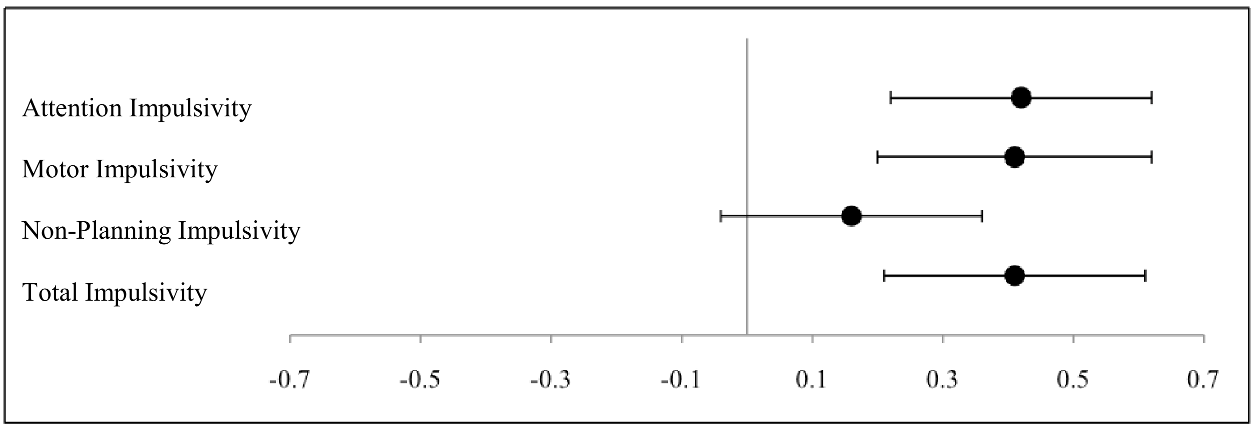
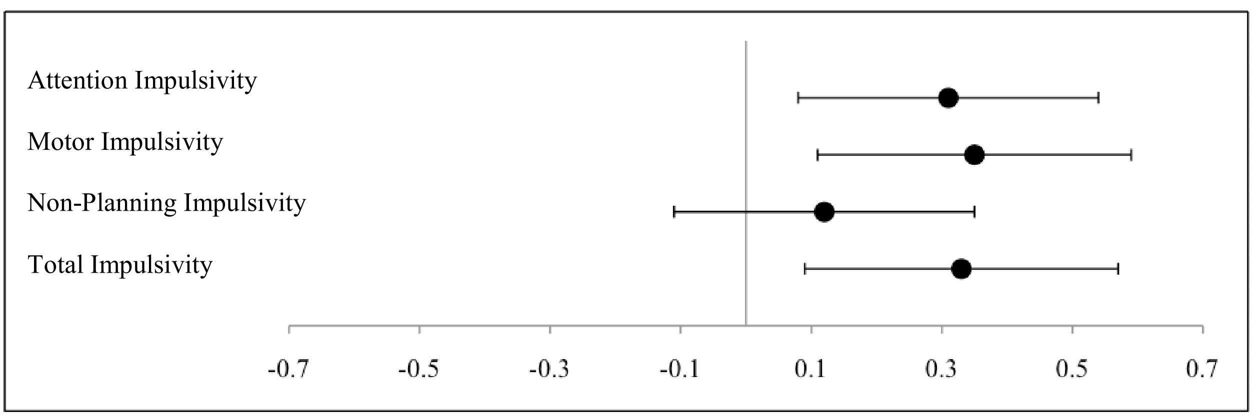


Figure 6. Risk-Taking Effect Sizes Between 1 and 2+ Previous SRC Groups

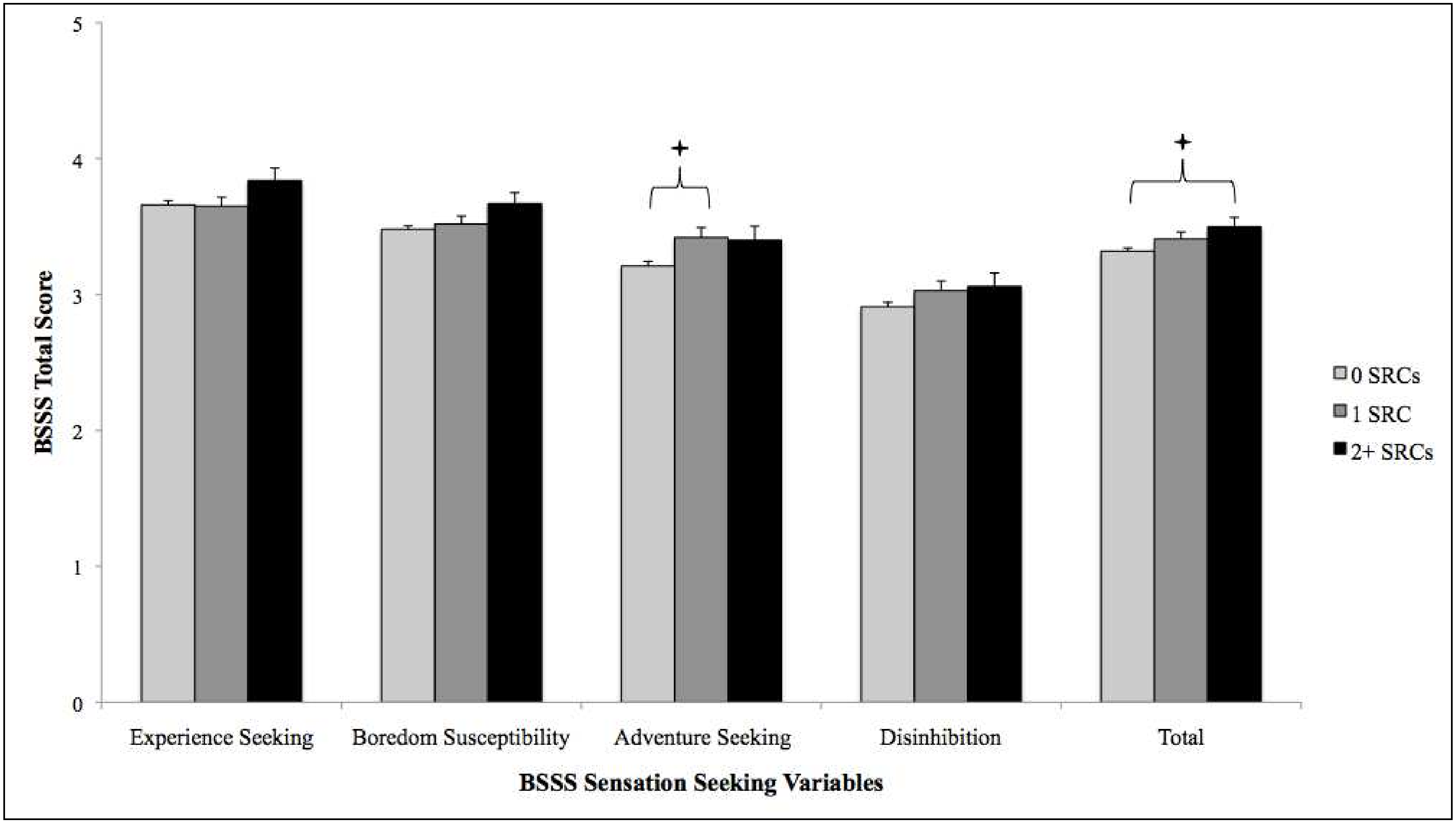


4.3. Sensation Seeking Needs

H2: Collegiate student-athletes with a history of SRC (i.e., 1 and 2+ SRCs) will have higher sensation seeking than those who have not sustained a concussion.

The hypothesis for sensation seeking was partially supported. The ANOCVA analyses indicated significant differences between previous SRC groups for the Brief Sensation Seeking boredom susceptibility [$F_{(1,207)}$=3.15, *p*=0.04], adventure seeking [$F_{(1,208)}$=5.18, *p*=0.01], and total sensation seeking [$F_{(1,214)}$=4.53, *p*=0.01] variables. No significant differences were found between previous SRC groups for the BSS experience seeking [$F_{(1,214)}$=2.15, *p*=0.12] and disinhibition [$F_{(1,205)}$=1.42, *p*=0.24] variables. For the BSS boredom susceptibility variable, Tukey post-hoc analyses found a trend toward significantly higher mean scores for the 2+ SRC compared to the 0 SRC group (MD=0.19), but fell short at *p*=0.06 (*d*=0.24). For the BSS adventure seeking variable, the 1 SRC group had significantly higher mean scores compared to the 0 SRC group (MD=0.22,*p*=0.02, *d*=0.20). Lastly, there was a statistically significant mean difference for the BSS total sensation seeking variable with the 2+ SRC group having higher scores compared to the 0 SRC group (MD=0.19,*p*=0.03, *d*=0.25) (see Table 3, Figures 7-10).

Figure 7. Sensation Seeking Differences Between Previous SRC Groups



✛ $p<0.05$

Figure 8. Sensation Seeking Effect Sizes Between 0 and 1 Previous SRC Groups

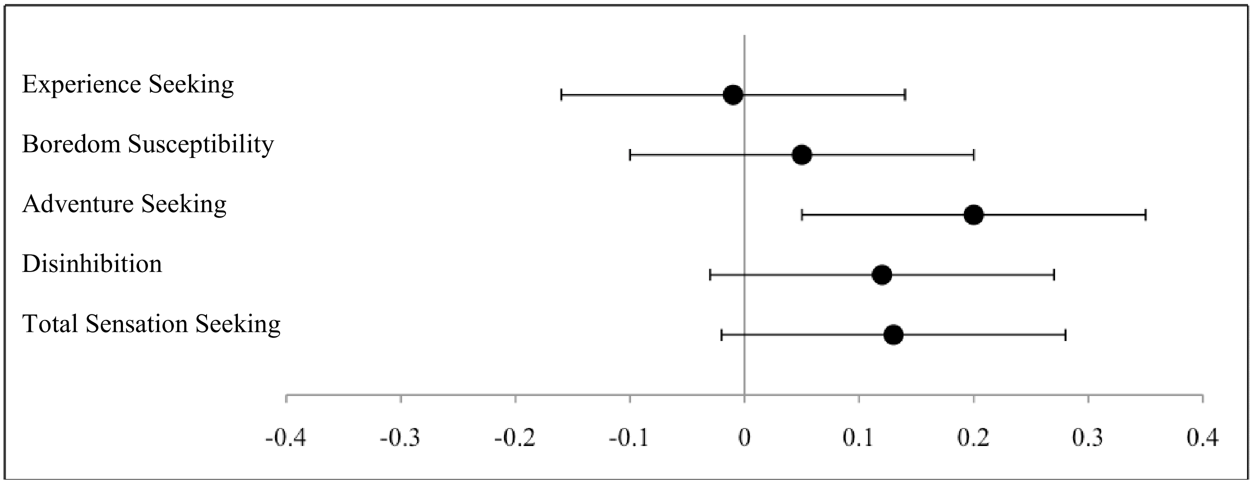


Figure 9. Sensation Seeking Effect Sizes Between 0 and 2+ Previous SRC Groups

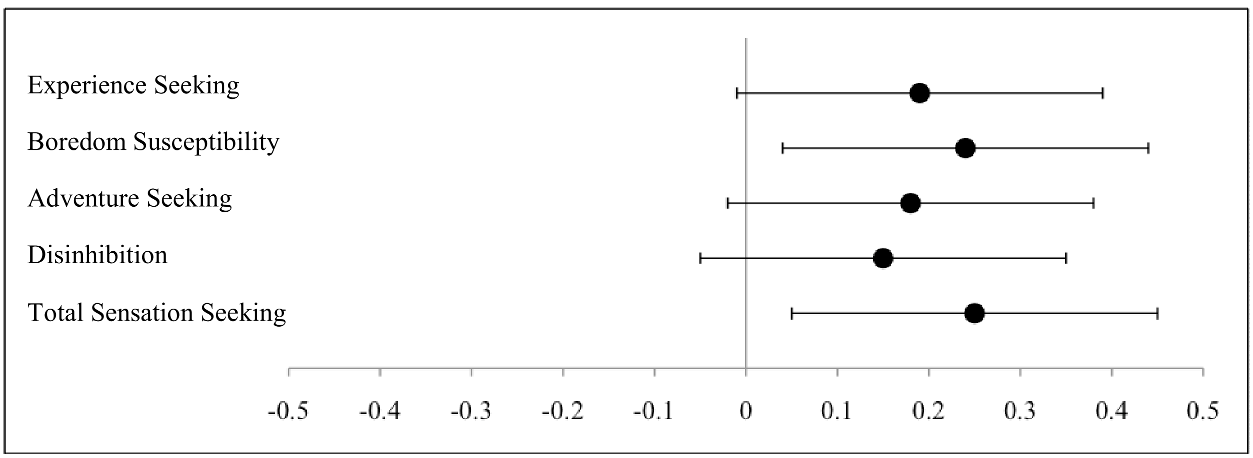
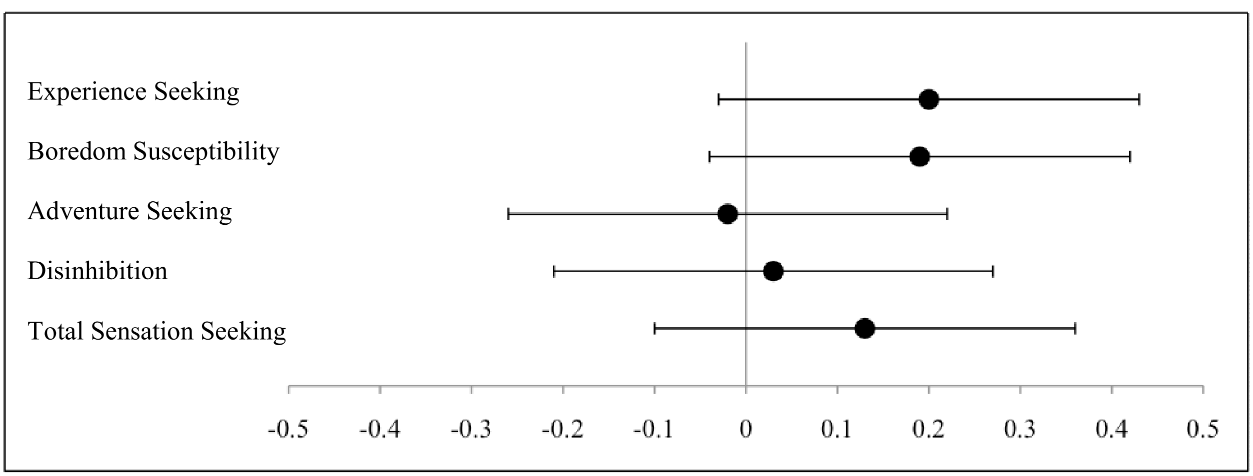


Figure 10. Sensation Seeking Effect Sizes Between 1 and 2+ Previous SRC Groups



4.4. Mood States

H3: Collegiate student-athletes with a history of SRC (i.e., 1 and 2+ SRCs) will have higher mood state than those who have not sustained a concussion.

The hypothesis for mood states was not supported. The ANCOVA analyses did not identify any statistically significant differences between previous SRC groups for the Brunel Mood Scale anger [$F_{(1,221)}$=0.32, p=0.73], confusion [$F_{(1,223)}$=0.53, p=0.59], depression [$F_{(1,223)}$=0.68, p=0.51], fatigue [$F_{(1,222)}$=0.46, p=0.63], tension [$F_{(1,224)}$=0.73, p=0.48], or vigor [$F_{(1,223)}$=0.72, p=0.49] variables (see Table 3, Figures 9-12).

Figure 11. Mood State Differences Between Previous SRC Groups

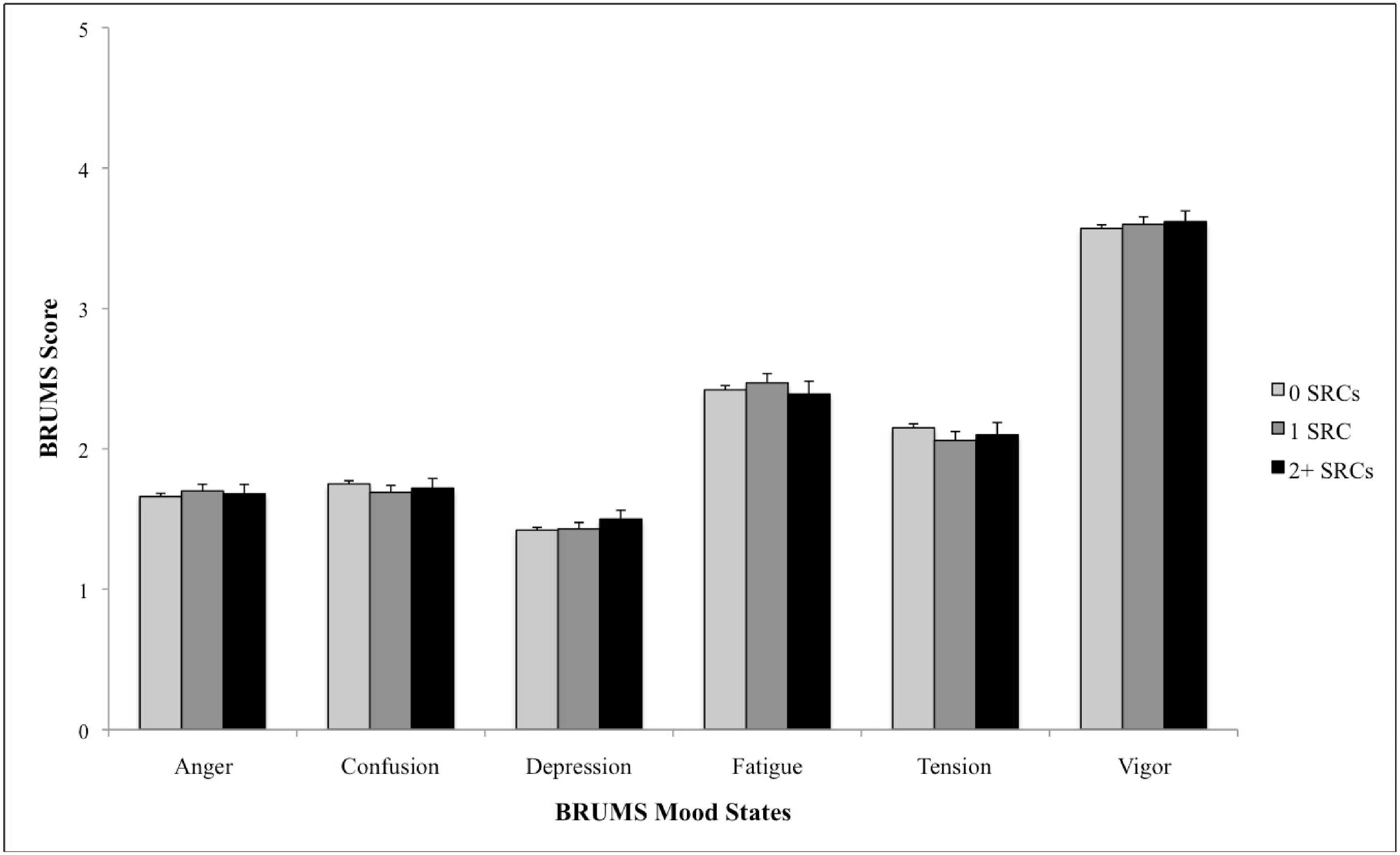


Figure 12. Mood State Effect Sizes Between 0 and 1 Previous SRC Groups

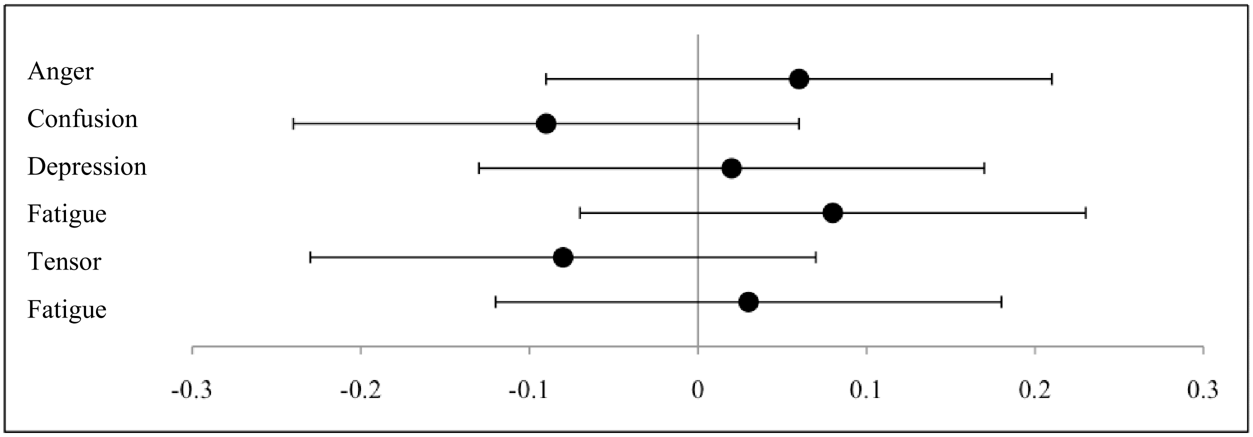


Figure 13. Mood State Effect Sizes Between 0 and 2+ Previous SRC Groups

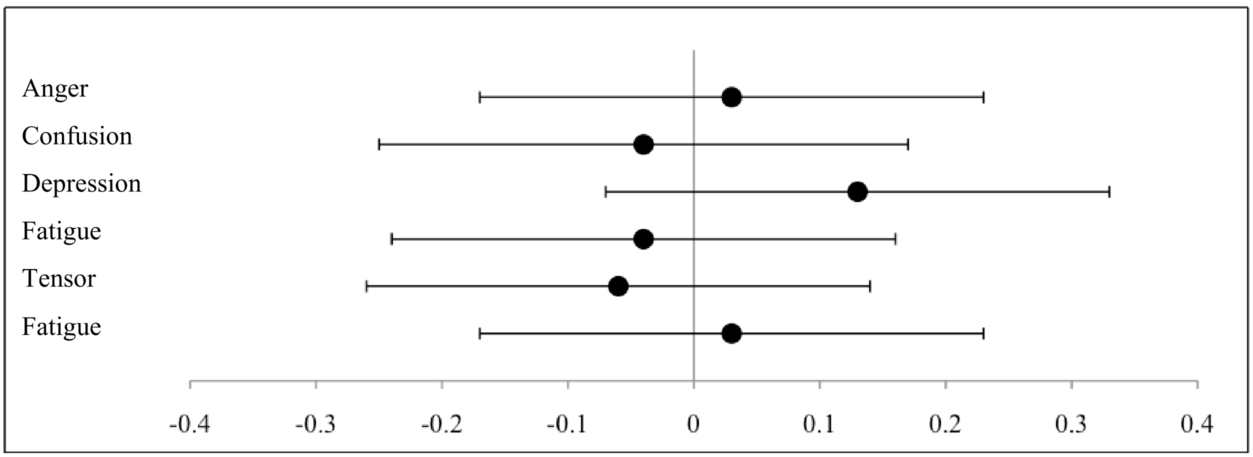
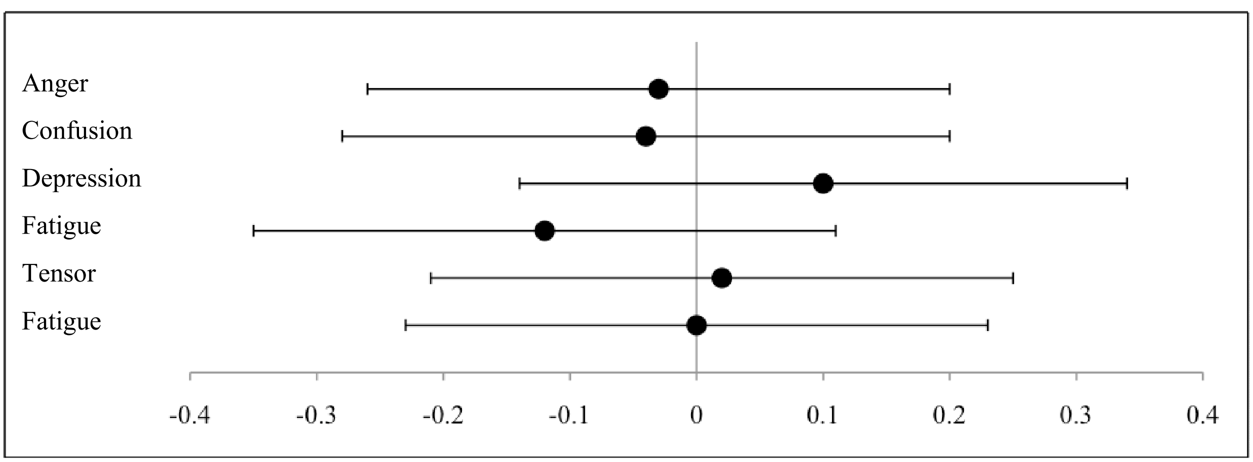


Figure 14. Mood State Effect Sizes Between 1 and 2+ Previous SRC Groups



4.5. Personality Traits

Research Question 1: Are there personality trait differences between collegiate student-athletes with and without a history of SRC (i.e., 1 and 2+ SRCs)?

The ANCOVA analyses did not identify any statistically significant differences between previous SRC groups for the Big Five Inventory extraversion [$F_{(1,242)}$=2.32, *p*=0.09], conscientiousness [$F_{(1,241)}$=0.71, *p*=0.49], neuroticism [$F_{(1,241)}$=1.23, *p*=0.29], openness [$F_{(1,241)}$=0.76, *p*=0.47], and agreeableness [$F_{(1,242)}$=0.00, *p*=1.0] variables (see Table 3, Figures 13-16).

Figure 15. Personality Trait Differences Between Previous SRC Groups

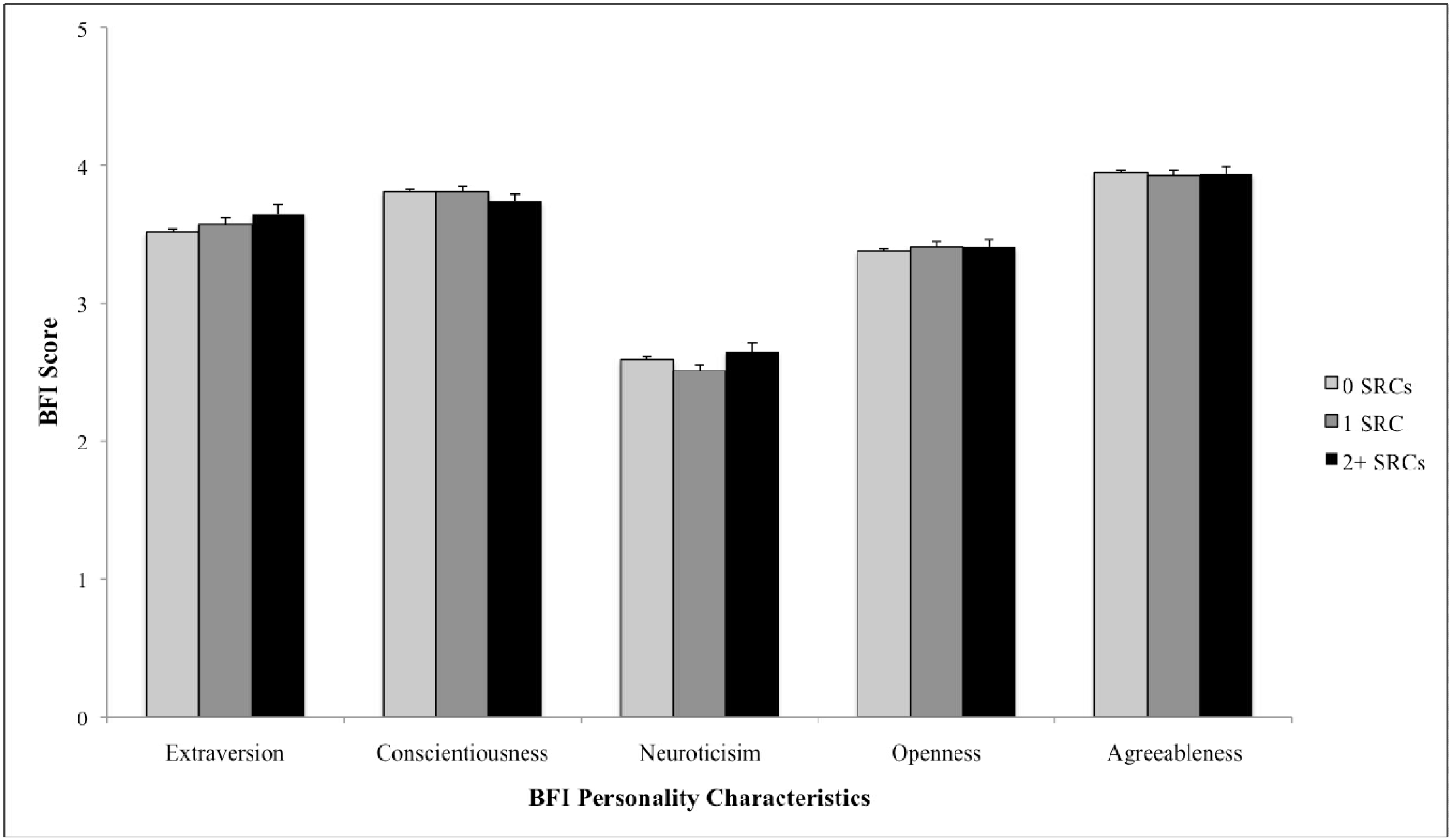


Figure 16. Personality Trait Effect Sizes Between 0 and 1 Previous SRC Groups

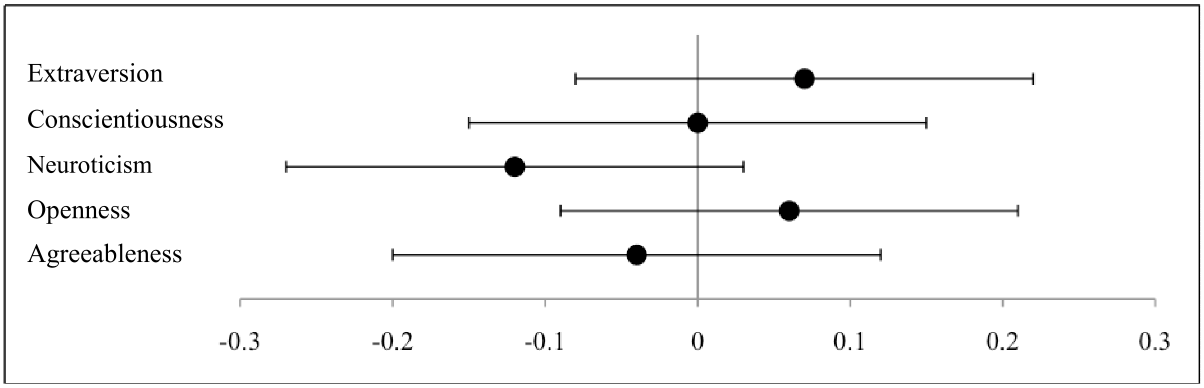


Figure 17. Personality Trait Effect Sizes Between 0 and 2+ Previous SRC Groups

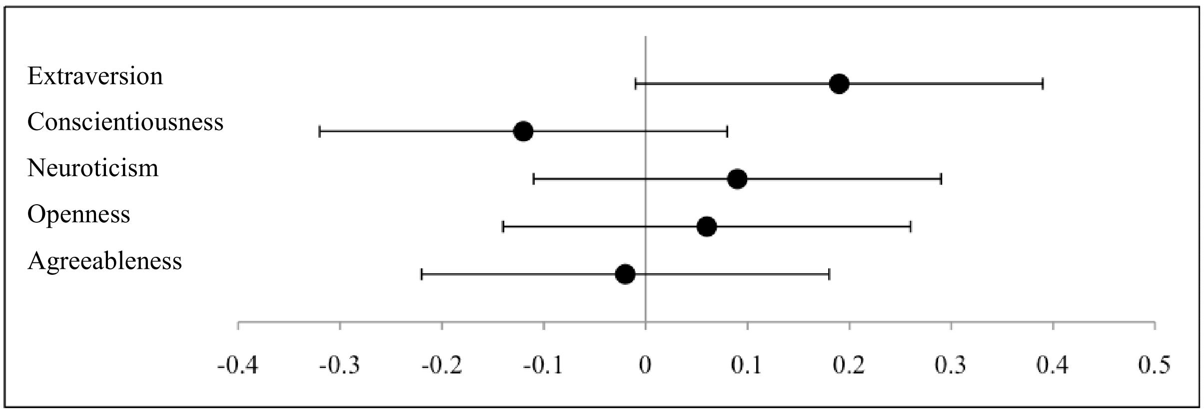
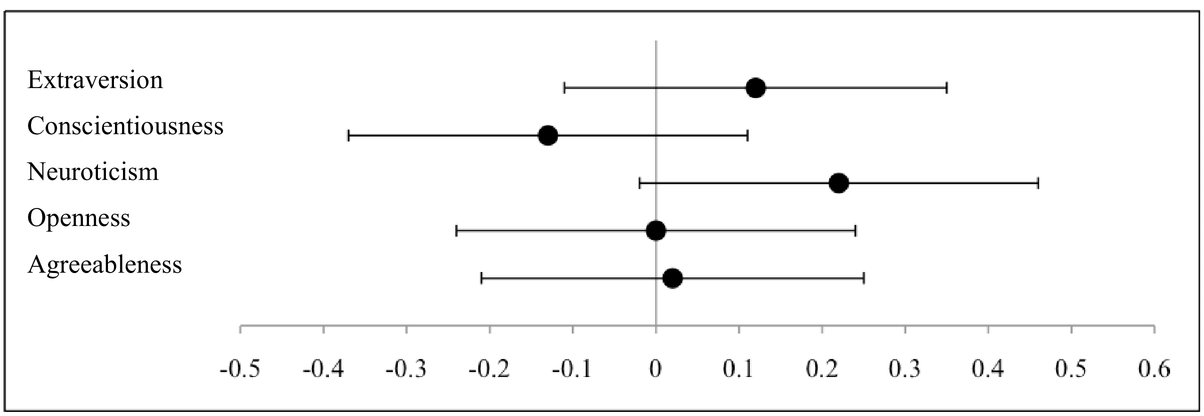


Figure 18. Personality Trait Effect Sizes Between 1 and 2+ Previous SRC Groups



4.6. Sport-Related Concussion Predictors

Research Question 2: Do risk-taking, sensation seeking, mood, and/or personality psychological variables predict SRC history (i.e., 1 and 2+ SRCs)?

The following variables were included in the multinomial logistic regression analysis: neuroticism, extraversion, openness to experience, agreeableness, conscientiousness, attention impulsivity, motor impulsivity, non-planning impulsivity, experience seeking, boredom susceptibility, thrill and adventure seeking, disinhibition, total sensation seeking, anger, confusion, depression, fatigue, tension, vigor, sex, and sport type. The regression identified BSS adventure seeking (b=0.24, p=0.01), BRUMS confusion (b=-0.43, p=0.03), and sport type (b=0.36, p=0.00) as significant predictors of inclusion in the 1 SRC group relative to the 0 SRC group. Additionally, BIS attention impulsivity (b=0.60, p=0.01), BRUMS depression (b=0.60, p=0.02), and sport type (b=0.45, p=0.00) were found to be significant predictors of inclusion in the 2+ SRC group relative to the 0 SRC group.

CHAPTER 5

DISCUSSION

5.1. Overview

This study focused on the psychological differences between collegiate student-athletes with and without a history of Sport-Related Concussions. Specifically, the psychological variables of interest were risk-taking behaviors, sensation seeking needs, mood states, and personality traits. Collegiate student-athletes completed a series of psychological assessments by answering questions about themselves and were divided into previous SRC history groups of 0, 1, and 2+. In addition to addressing psychological differences between groups, a secondary aim of this study was to investigate psychological variables that predicted a history of concussive injury of our participants.

The results of this study demonstrate that there are moderate differences in risk-taking behaviors and sensation seeking needs between SRC history groups. This study provides support that the relationship between psychological variables and SRC is important and warrants additional investigation. Further defining this relationship may add valuable information that could help aid in the prevention and management of concussive injuries.

5.2. Risk-Taking Behaviors

Three out of the four risk-taking variables included in this study differed between SRC history groups. Attention, motor, and total impulsivity were all significantly different between the 0 and 2+ SRC groups and 1 and 2+ SRC groups with effect sizes all falling in the moderate range. Also, attention impulsivity was identified as a significant predictor of 2+ previous SRCs. The results did not identify any significant differences between the 0 and 1 SRC groups for any of the impulsivity variables. Due to this, it can be interpreted that risk-taking may not be an important psychological variable for those sustaining a single SRC, but may be more important when considering those with a history of multiple SRCs. These findings partially supported the hypothesis that collegiate student-athletes with a history of 1 or 2+ SRCs would have higher risk-taking behaviors than those who had sustained 0. Based on the results, it would be more accurate to conclude that collegiate student-athletes with a history of 2+ previous SRC had higher attentional, motor, and total risk-taking behaviors compared to those who had sustained 0 or 1 SRC. Additionally, the significant risk-taking sex differences will not be further discussed at this time, as this section will only focus on the variables of interest related to the proposed hypothesis.

As stated before, there is no previous research investigating the relationship between risk-taking behaviors and SRC that this study can be directly compared to. The risk-taking results of this study may be partially explained through a deeper investigation into the subject characteristics of the 2+ SRC group. Football and male lacrosse athletes made up 31.2% (n=34) of the 109 total collegiate student-athletes included in the 2+ SRC group. In fact, a quarter of the male lacrosse subjects included in this study reported a history of multiple SRCs. Both football and lacrosse are equipment-intensive sports where contact and collision are an assumed risk when participating. Due to the increased intensity and physical nature of these sports, athletes have a greater chance of sustaining an injury compared to non-contact sports.

Furthermore, a systematic review of six case-control studies concluded that, in general, individuals who are higher risk-takers have an increased probability for sustaining an injury compared to low risk-takers (Turner, McClure, & Pirozzo, 2004). An investigation on collegiate athletic injury epidemiology found football to have the highest concussive injury rate ranging between 0.37-0.54 SRCs per 1,000 athlete-exposures for practices and games combined, while men's lacrosse ranks the fourth highest overall with 0.26 SRC per 1,000 athlete-exposures (Hootman, Dick, & Agel, 2007). These findings suggest that a large portion of athletes making up the 2+ SRC group are also the athletes participating in sports with high prevalence rates of concussive injury.

Risk compensation may be another explanation for why the 2+ SRC group had significantly higher risk-taking scores compared to the 0 and 1 SRC groups. There is speculation that the use of protective equipment, such as helmets and shoulder pads in football and men's lacrosse, may produce a false sense of protection (Hagel & Meeuwisse, 2004) and promote a riskier style of play (Broglio et al., 2011; Mihalik et al., 2007). A study was recently completed that investigated differences in the number of head impacts during one athlete-exposure between collegiate football players that completed a helmetless-tackling intervention throughout one season (Swartz et al., 2015). Results showed that the helmetless-tackling intervention group recorded 28% less head impacts per athlete-exposure by the end of one football season of training compared to pre-season measurements. Additionally, the intervention group had an average of 30% fewer head impacts per athlete-exposure by the end of the season compared to the control group. This study illuminates the reality of risk compensation in equipment-intensive sports, and shows that the solution may be to modify behavior rather than increasing the sophistication of protective gear. As for the current study, 57.8% (n=63) of those in the 2+ SRC group play sports that have some form of personal protective equipment that is mandated for participation. Therefore, the increased risk-taking behaviors in the 2+ SRC group may be partially due to an increase in risk compensation and aggressive play due to the use of protective equipment by the majority of subjects. More research on risk compensation is needed across different sports and age ranges to further understand this phenomenon.

Overall, I have 2 different thoughts on why the 2+ SRC had higher risk-taking scores compared to the 0 and 1 SRC group. Due to their increased impulsiveness, high-risk-taking athletes may not take the time to critically think about the potential for injury before they make a daring play. Therefore, my first thought is that individuals who are naturally high risk-takers will put themselves into dangerous sport situations more frequently than low risk-takers. This would inevitably lead to the high risk-takers sustaining more SRC compared to low risk-taking athletes. My second thought is that perhaps a history of multiple SRCs and subconcussive impacts leads to an increase in risk-taking behaviors. Previous research using accelerometers found that the frontal region of the head sustains the most impacts during ice hockey and football (Mihalik et al., 2008; Guskiewicz et al., 2007). This is also the region of the brain which houses risk-taking decision making processes (Rao, Korczykowski, Pluta, Hoang, & Detre, 2008). Therefore, the cumulative effects of head impacts to the prefrontal cortex in the frontal region of the brain may cause a decrease in one's protective intuitions and cause them to adopt more risk-taking behaviors than they would have prior to sustaining multiple SRCS. This investigation on risk-taking behaviors and SRC is the first of its kind, and future longitudinal studies are needed to further clarify and strengthen these findings.

5.3. Sensation Seeking Needs

This study found that adventure seeking scores differed between the 0 and 1 SRC groups, while the total sensation seeking scores differed between the 0 and 2+ SRC groups. There was also a trend toward a significant difference between the 0 and 2+ SRC groups for boredom susceptibility. No significant differences were identified between groups for experience seeking or disinhibition. Additionally, adventure seeking was identified as a significant predictor of 1 previous SRCs. Therefore, the hypothesis that collegiate student-athletes with a history of 1 or

2+ SRCs will have higher sensations seeking needs compared to the 0 SRC group is only partially supported.

These sensation seeking results align with a study that concluded that rugby players who had higher SSS-V scores also had higher SRC-incidence rates compared to rugby players with low to medium SSS-V scores (Hollis et al., 2009). Although there were methodological variances between studies, it is possible to make general comparison of conclusions. In both studies, there was a connection between higher sensation seeking scores and SRC. The results of rugby study indicated that high sensation seeking rugby players sustain SRCs at a higher rate compared to low sensation seeking rugby players (Hollis et al., 2009). The results of the current study imply that collegiate student-athletes who have sustained 2+ SRCs have higher sensation seeking scores compared to those who have a history of 0 or 1 SRC. It is difficult to make a direct comparison between the results from this study and Hollis et al. because mean SSS-V scores were not reported for the rugby subjects. In addition, it was not clearly defined how high versus low SSS-V score groups were determined, and SRC injury rates were investigated rather than mean group differences.

The sensation seeking results of this study also have similarities to the results from another investigation that found group differences for adventure seeking and a trend toward significance for boredom susceptibility (O'Jile et al., 2004). Researchers also found a trend toward significant group differences for the total sensation seeking scores, which this study found as being statistically significant. The major methodological differences between the two studies are that this study focused on SRC in collegiate student-athletes, where the previous study focused on head injury in the general collegiate student population. The differing findings may be explained by the difference in subject grouping for each study. This study compared 0, 1, 2+ SRC groups, while the other only examined differences between head-injured and non-head injured groups. It is unclear how many, if any, of the head-injured subjects had sustained multiple head injuries and how that may have impacted the results. Another reason may be due to the larger sample size in this study compare to the aforementioned study. Once again, there are difficulties in making direct statistical comparisons between the two studies due to different reporting formats. The previous investigation reported average cumulative composite SSS-V scores, while the current study used the average mean composite score for each variable.

Overall, although the sensation seeking hypothesis was not fully supported, the total sensation seeking score had significant findings. The total score is a combination of all the composite variables together and may be more important than considering each individual subset of sensation seeking. When looking at the overall trend of the sensation seeking scores for all SRC groups, a large majority of group means fell above a moderate score (3-Neither Disagree nor Agree) on the BSSS. This shows that the collegiate student-athletes in this sample were on the higher end of sensation seeking needs in general. Additionally, the significant mean total sensation seeking difference between the 0 and 2+ SRC groups is similar to the total risk-taking result described above. This finding, in addition to the lack of significant differences between the 0 and 1 SRC groups, adds evidence to the argument that risk-taking and sensation seeking may not be key psychological variables in those sustaining a single SRC, but may play a more pronounced role when considering a history of multiple SRCs in collegiate student-athletes.

5.4. Mood States

No mood state variables (anger, confusion, depression, fatigue, tension, vigor) investigated in this study differed between SRC groups. This goes against the hypothesis that collegiate student-athletes with a history of SRC would have elevated mood state scores compared to those who had never sustained a SRC. Although group differences were not identified, confusion was found to be a predictor of having sustained 1 previous SRC and depression a predictor of a history of 2+ SRCs.

The lack of SRC group mood state differences is comparable to one other study (Mainwaring et al., 2004). The current study had a greater sample size and used a different mood state assessment, but similar mood state results were found for collegiate student-athletes' post-recovery mood state scores between the two investigations. Previous research found that collegiate student-athletes suffering an acute SRC had significantly higher post-injury Profile of Mood State (POMS) depression, confusion, and total mood disturbance scores compared to a healthy control group (Mainwaring et al., 2004). These group differences dissipated by three weeks post-injury with both the SRC and control subjects presenting with similarly low POMS scores. These results suggest an influx in depression and confusion during the initial stages of SRC recovery that resolve back to normalcy as they recover. This may help explain why our study did not find mood state differences as all of our subjects were at least three-months post-SRC and out of the acute injury phase.

This study's lack of SRC post-recovery depression findings was in contrast to previous research (Guskiewicz et al., 2007; Kerr et al., 2012; Kontos et al., 2012; Chrisman & Richardson, 2014). One previous investigation determined that there was an association between recurrent head injuries and clinical depression in retired professional football players, and that the prevalence of depression increases as the number of previous concussions increases (Guskiewicz et al., 2007). Over a nine-year study period, another study found that the risk of clinical depression diagnosis increased as the number of self-report concussions increased in a sample of retired professional football players (Kerr et al., 2012). Similarly, a more recent investigation found that adolescents with a history of any type of concussion were at a 3.3 times greater risk for being diagnosed with clinical depression compared to those who did not report a history of concussion (Chrisman & Richardson, 2014). Differing findings between the current study and the previous literature may be due to methodological differences. The aforementioned researchers did not have their participants complete any type of psychological assessments and relied on subject self-reporting of clinical depression diagnosis and previous history of SRC, whereas this study utilized the BRUMS mood assessment.

Additionally, subject populations differed between studies. This study focused on a sample of diverse collegiate student-athletes, while the previous studies were only interested in retired professional football players (Guskiewicz et al., 2007; Kerr et al., 2012). It would be inappropriate to make a comparison between collegiate student-athletes in this study and a retired professional football athlete sample. Retired professional football players have more years of participation, and thus have an increased exposure to potential injuries compared to collegiate student-athletes. Additionally, a retired professional football sample is made up of individuals who participated in a high-risk sport with more opportunity for concussive and sub-concussive injuries. Only a quarter of this study's collegiate student-athlete sample participated in a high-risk sport, so the overall number of sub-concussive athlete-exposures for the sample would inevitably be less.

It is also difficult to compare a collegiate student-athlete population to one of general population adolescents. Chrisman and Richardson (2014) collected information from parents on a large sample of the general adolescent population with ages ranging from 11 to 17. Their population was variable and did not specifically focus on youth sport participants. The difference in age, maturity, and level of daily physical activity between collegiate student-athletes and general adolescents is too indefinite to make associative result comparisons. Additionally, it is unclear what types of head injuries the adolescent subjects sustained and how it related to their diagnosis of clinical depression.

Although confusion and depression were found to be predictors of 1 and 2+ previous SRCs, both had a small effect when looking at SRC group differences. These findings may be attributed to the nature of the mood state scale used for this study. The BRUMS is not comparable to formal clinical depression diagnostic aids, such as the Beck Depression Inventory. The BRUMS is designed to measure transient mood states and not to identify clinical psychological diagnoses. Overall, the results of this investigation concluded that there were no mood state differences between collegiate student-athletes with and without a history of SRC in the study sample. Due to the lack of group differences, these mood state findings may be interpreted as a representation of the average affect for collegiate student-athletes as low anger, low confusion, low depression, mild fatigue, mild tension, and moderate vigor.

5.5. Personality Traits

There were no personality trait differences between SRC groups for this study. Additionally, no personality traits were identified as predictive factors for having sustained a previous SRC in the collegiate student-athlete sample. There are no previous studies that investigated personality traits and SRC directly, but there is one study that retrospectively looked at personality traits in general mTBI patients (Rush et al., 2004). This investigation compared the personality traits of acute mTBI patients, acute orthopedic injury patients, and healthy control subjects who were recruited from an emergency department. The authors did not find any personality differences between the mTBI, orthopedic injury, or control groups. Subjects were from the general population with acute mTBI of varying mechanisms and unknown concussion history, while this study focused on collegiate student-athletes who had sustained and fully-recovered from SRCs. Regardless of these methodological differences, the findings are similar between studies.

These results may be explained by the innate nature of personality traits. Personality tends to remain fairly consistent overtime (Conley, 1985; Costa & McCrae, 1994; Roberts & DelVecchio, 2000). An individual's personality will adapt to unforeseen or traumatic life experiences, but the normal evolutionary process of personality development slows as one ages and life becomes more stable and repetitive (Roberts & DelVecchio, 2000). A typical mTBI in the general population or SRC in an athletic population that resolves within 7-10 days may not be distressing enough to cause a change in personality traits. Therefore, it is not surprising that group personality differences were not identified in either study.

Overall, there were no differences in extraversion, conscientiousness, neuroticism, openness, or agreeableness between collegiate student-athletes with and without a history of SRC. Similar to mood states, the lack of group differences may indicate that the findings of this study represent the general personality profile of collegiate student-athletes. The collegiate student-athlete sample in this study was high in extraversion, conscientiousness, openness, and agreeableness, and low in neuroticism. This finding has consistency with those found by others who compared athletes' personality to non-athlete control groups and found that athletes were higher in extraversion and conscientious and lower in neuroticism than non-athletes (Nia & Besharat, 2010). These findings also mimic those found by previous researchers for athletes and other physically active populations (Rhodes, Courneya, & Bobick, 2001; Conner & Abraham, 2001; Rhodes & Smith, 2006; Tafti, Pakdaman, & Asgari, 2008; Saklofske, Austin, Rohr, & Andrews, 2007; Arai & Hisamichi, 1998; Potgieter & Venter, 1995; Yeung & Hemsley, 1997;

Paunonen, 2003). It is speculated that this relationship between personality and sport may be circular in nature in that high extraversion, high conscientiousness, and low neuroticism prepare the individual for athletic participation, while at the same time athletic participation provides a mechanism for developing these particular characteristics (Nia & Besharat, 2010).

5.6. Limitations

This study had a number of limitations that must be considered. First, this was a retrospective investigation of psychological variables and SRC history. Due to this, participant grouping was largely based upon self-reported information about previous SRCs that they had sustained. Relying on the subject's capacity to remember their previous injuries is not as accurate as having injury verification from medical documentation. The retrospective nature of this study also limits the ability to define causative relationships between the psychological variables and SRC history, as it is unknown what level of risk-taking and sensation seeking were present prior to injury. These limitations were accepted due to a short data collection timeframe and the inability to access participants' medical records. Although SRC self-reporting is not ideal, it is commonly used in research and has been found to have moderate reliability across a nine-year time span (Kerr, Marshall, & Guskiewicz, 2012).

Another possible limitation of this study was the risk-taking instrument selection. There is a lack of previous literature on risk-taking in traditional sports (i.e. football, basketball, soccer), which made survey selection difficult. The available risk-taking literature dealt with extreme sports (i.e. mountaineering, hang gliding, skiing), and the instrumentation used was not adaptable for traditional sport. Due to this, a general measure of risk-taking impulsivity was chosen. The scores of the Barratt Impulsiveness Scale-15 represent the collegiate student-athletes risk-taking tendencies in everyday life tasks (i.e. planning for the future, task concentration), and it is unknown how these scores translate into risky sport behaviors that make athletes more susceptible to sustaining an injury (i.e. disregarding sport rules, completing dangerous playing maneuvers). This limitation could not be overcome due to the lack of survey availability and the time constraints that prohibited the development of a risk-taking scale for traditional sports. Therefore, the interpretation of results should be from a general risk-taking perspective rather than a sport-specific one.

The mood state survey selection also limited this study's interpretation and comparability to previous research. The Brunel Mood Scale is significantly shorter compared to formal instrumentation used in clinical psychology that can have 100+ items. It was selected for this study in order to keep the total survey time down, thus maintaining the collegiate student-athletes' interest long enough to decrease the likelihood of early survey termination. The BRUMS is a measure of momentary mood states and not clinical psychological issues. Therefore, the results of fleeting mood states for this study cannot be compared to the long-term chronic issues, such as clinical depression and neurocognitive dysfunction, investigated in previous SRC investigations.

The last notable limitation of this study was its sample. Although both sexes and a variety of traditional sports were included, this study focused only on the college setting. The results of this study are not generalizable to all those who participate in athletics. The motivation for collegiate sport participation may vary from youth, professional, and masters athletes, so it cannot be assumed that their psychological profiles are similar. Additionally, our sample of collegiate student-athletes came from four NCAA institutions: one Division-I, two Division-II, and one Division-III. These institutions were in Michigan and Pennsylvania and only make up a small portion of the total collegiate student-athlete population in the United States. It is unclear if the findings of this study are representative of the collegiate student-athlete population as a whole. This limitation was acknowledged and accepted due to time constraints and the degree of monetary resources.

5.7. Future Research Considerations

Based upon the risk-taking and sensation seeking findings of this study, further research is needed to investigate the role of psychology in SRC prevention, identification, and management. For example, to determine if there is a causal relationship between SRC and the presence of increased risk-taking behaviors and sensation seeking needs, a longitudinal study that includes a pre/post-test design is warranted. This study design would be beneficial in helping to determine if elevated risk-taking and/or sensation seeking are risk factors for sustaining a SRC in an athletic population. It would also provide baseline psychological information that post-SRC measurements could be compared to in order to find out if a concussive injury causes any acute or long-term alterations in risk-taking, sensation seeking, mood, or personality.

It would be advantageous if this longitudinal study utilized a risk-taking assessment that is tailored specifically to traditional sport participation. Therefore, the development and validation of a traditional sport risk-taking behavior assessment should be considered a priority. This assessment should focus on sport rule compliance, proper safety equipment usage, style of play, and bodily awareness. This assessment could be paired with video analysis of sport participation to help identify high risk-taking athletes. Safer technique variations could then be introduced to help decrease the chance of sustaining an injury.

As for mood states and personality traits, it would be beneficial to include them in a longitudinal investigation even though no significant SRC group differences were observed in this study. Both pre-concussive personality and mood have been linked to post-concussive symptom reporting and prolonged recovery (Garden, Sullivan, & Lange, 2010, Yang et al., 2015, Covassin et al., 2012). In addition to being used for research, individual personality and mood information could provide sports medicine clinicians with an additional resource for tracking psychological recovery during SRC management.

In addition to the considerations above, expanding the longitudinal study to include high school and professional athletes would be fitting. Collecting from three different populations at varying levels of competition would make the findings more generalizable to all athletes. It could also be productive to look for psychological differences between groups in order to determine if there are variations in the psychological profile as the time spent in sport and competition level increase.

Lastly, an investigation on the psychological readiness to return to play and fear of reinjury following a SRC is also needed, as there is no previous research investigating these issues. These topics are natural additions to the aforementioned longitudinal study. Being able to identify if risk-taking, sensation seeking, mood state, and/or personality traits of an individual are related to fear of sustaining another SRC or hesitance to resume participation could prove valuable when considering psychological recovery and return to play decision-making. Overall, there is much to be learned about the psychological processes related to SRC. The true short-term, long-term, and cumulative effects of the injury on the psyche have yet to be determined.

5.8. Conclusion

This is the only study to date to examine psychological differences between collegiate student-athletes with varying SRC histories. While mood and personality do not appear to differ based upon SRC history, total risk-taking and sensation seeking scores were higher in collegiate student-athletes with a history of multiple SRCs. As these scores did not differ between the 0 and

1 SRC groups, risk-taking and sensation seeking may not play a role in a single SRC, but could be psychological variables to consider when dealing with a history of multiple SRCs.

Additionally, being able to identify athletes who are higher in risk-taking and sensation seeking could prove clinically beneficial from a sports medicine standpoint. If a high risk-taking and sensation seeking athlete is identified, an intervention could be put into place in order to help decrease their risk for sustaining a SRC. This intervention could include individualized concussion education, a biomechanical breakdown of sport maneuvers (e.g. football tackling, soccer heading), and subsequent style of play modifications. This may be especially important for those who participate in equipment intensive sports that inherently provide more opportunities to sustain a SRC. In conclusion, more research is needed to strengthen the findings of this study and determine the true nature of the relationship between SRC occurrence, risk-taking behaviors, and sensation seeking needs.

APPENDICES

Appendix A: Informed Consent

EXPLORING PSYCHOLOGICAL VARIABLES BETWEEN COLLEGIATE STUDENT-ATHLETES WITH AND WITHOUT A HISTORY OF SPORT-RELATED CONCUSSION

For questions regarding this study, Please contact:
Tracey Covassin, Ph.D., ATC
Protection Program
Department of Kinesiology
Michigan State University
Phone: (517) 353-2010
E-mail: covassin@msu.edu

OR

Erica Beidler, M.Ed., ATC
Department of Kinesiology
Michigan State University
E-mail: beidlere@msu.edu

For questions regarding your rights as a research participant, please contact:
Michigan State University's Human Research

408 West Circle Drive #207
Michigan State University
East Lansing, MI 48824
E-mail: irb@msu.edu
Phone: (517) 355-2180
Fax: (517) 432-4503

Purpose:

The purpose of this study is to investigate the differences in personality traits, risk-taking behaviors, sensation seeking needs, and mood states between collegiate student-athletes with and without a history of sport-related concussion.

Consent:

You have been selected to be a participant in this research study. Your participation in the research study is voluntary and subjects must be at least 18 years of age or older. You have the right to say no. Refusal to participate in the study will not affect you or your athletic participation. You may discontinue participation in the study at any time without penalty. You may change your mind at any time and withdraw from the study. You may choose not to answer specific questions or to stop participating at any time.

You are receiving this Informed Consent Waiver as a prospective participant in this research study. Your decision to complete the surveys indicates your voluntary agreement to participate in this study.

Whether you participate or not, will have no effect on your athletic participation.

General Experimental Procedures:

You will be completing a one-time anonymous survey that includes the following components: demographic information questionnaire, sport-related concussion history questionnaire, the Big Five Inventory (BFI) of personality traits, the Barratt Impulsiveness Scale (BIS-15) of risk-taking behaviors, the Brief Sensation Seeking Scale (BSSS) of sensation seeking needs, and the Brunel Mood Scale (BRUMS) of mood states. The data will be used for the advancement of sport-related concussion knowledge. The approximate time to complete the surveys is 15-20 minutes.

Possible Risks:

There are no foreseeable risks associated with participation in this study. Please be assured that you may choose not to answer certain questions and still continue to participate in this study. **All answers are strictly confidential and will not be released to anyone. Responses will not be seen or used by the sports medicine team for any reason.**

Confidentiality/Anonymity:

Your participation in this study is completely voluntary. The only people who have access to your answers are the researchers and the Michigan State Human Research Protection Program. The information recorded during the study will remain confidential. Confidentiality will be protected by; (a) results of this study may be published or presented at professional meetings, but the identities of all research participants will remain anonymous; and (b) all data will be stored in a computer that is password protected, as well as all surveys will remain in an office under double lock and key for 3 years. Your privacy will be protected to the maximum extent allowable by law. You may also discontinue participation at any time without penalty. Your participation in this research project will not involve any additional costs to you or your health care insurer.

Institutional Contacts:

If you have concerns or questions about this study, such as scientific issues, how to do any part of it, or to report an injury, please contact the researcher coordinator, Erica Beidler, via an e-mail to *beidlere@msu.edu* or regular mail at *Department of Kinesiology, Michigan State University, East Lansing, MI 48824.*

If you have questions or concerns about your role and rights as a research participant, would like to obtain information or offer input, or would like to register a complaint about this study, you may contact, anonymously if you wish, the Michigan State University's Human Research Protection Program at 517-355-2180, Fax 517-432-4503, or e-mail irb@msu.edu or regular mail at Olds Hall, 408 West Circle Drive #207, MSU, East Lansing, MI 48824.

You are voluntarily agreeing to participate by completing the form.

Appendix B: Demographic Information

Are you 18 years or older?

(Please circle your selection)

Yes No

*** If you answered “No” to question #1, do not complete the rest of the survey and please turn it in at this time.

2a. Are you suffering from or currently receiving treatment for a concussion?
(Please circle your selection)

Yes No

2b. Have you sustained a concussion in the past 3 months?
(Please circle your selection)

Yes No

*** If you answered “Yes” to question #2a or b, do not complete the rest of the survey and please turn it in at this time.

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3. Are you currently suffering from a musculoskeletal injury (i.e. broken bone, strained muscle, sprained joint) and/or receiving sports medicine rehabilitation or treatment?
(Please circle your selection)

Yes No

*** If you answered “Yes” to question #3, do not complete the rest of the survey and please turn it in at this time.

4. Sex: (Please circle your selection)

Male Female

5. Height: ____________________ (feet' inches")

6. Weight: ______________________ (pounds)

7. Ethnicity: (Please circle your selection)

White Black Hispanic/Latino Asian

American Indian Mixed Race Other

8. What year of college are you entering? (Please circle your selection)

1st 2nd 3rd 4th 5th Graduate

9. What is your current college grade point average (GPA)? (Please circle your selection)

4.0 - 3.6 3.5 - 3.1 3.0 - 2.6 2.5-2.1 ≤ 2.0 I do not know

10. Place an "X" on the line next to the collegiate sport that you participate in:

_______ Football
_______ Men's Soccer
_______ Women's Soccer
_______ Wrestling
_______ Women's Volleyball
_______ Women's Field Hockey
_______ Men's Golf
_______ Women's Golf
_______ Men's Cross Country
_______ Women's Cross Country
_______ Men's Basketball
_______ Women's Basketball
_______ Men's Tennis
_______ Women's Tennis
_______ Men's Water Polo
_______ Women's Water Polo
_______ Rifle
_______ Men's Gymnastics
_______ Women's Gymnastics
_______ Men's Swimming & Diving
_______ Women's Swimming & Diving
_______ Men's Ice Hockey
_______ Women's Ice Hockey
_______ Women's Rowing
_______ Men's Lacrosse
_______ Women's Lacrosse
_______ Baseball
_______ Softball
_______ Men's Track & Field
_______ Women's Track & Field
_______ Women's Bowling
_______ Men's Fencing
_______ Women's Fencing
_______ Skiing

11. What position do you play? ____
(i.e. offense, defense, special teams)

12. What NCAA Division level that do you compete in? (Please circle your selection)

Division-I Division-II Division-III Other: ________________________

13. Approximately how many musculoskeletal injuries (i.e. broken bone, strained muscle, sprained joint) have you sustained previously while playing sports? (Please place # on line)

____

14. Do any of the following apply to you? (Please check all that apply)

_______ Diagnosed with a Learning Disability

_______ Diagnosed with ADD/ADHD

_______ Diagnosed with Depression or Anxiety

_______ Received Speech Therapy

_______ Repeated a Grade

_______ Attended Special Education Classes

15. Do you take any medications regularly? (Please list on line below)

____

16. Please circle "Yes" or "No" for each statement as it relates to you:

Yes No Treatment received for headaches by a physician

Yes No Treatment for migraine headaches by a physician

Yes No Treatment for epilepsy/seizures

Yes No Treatment for brain surgery

Yes No Treatment for meningitis

Yes No Treatment for substance/alcohol abuse

Yes No Treatment for psychiatric conditions, such as depression or anxiety

Appendix C: Sport-Related Concussion History

17. Have you ever been diagnosed with a concussion by a medical professional (i.e. doctor, athletic trainer, physician assistant)? (Please circle your selection)

Yes No

18. If yes, please provide information on your concussion(s) starting with the <u>MOST RECENT</u> first:

<u>Diagnosed Concussion #1</u>

Date of concussion: ________ /________ (approximate month/year)

Circle the option that best describes what you were doing when this concussion was sustained?

A. While playing traditional sports (i.e. football, basketball, soccer, etc.)
B. While participating in extreme sports (i.e., snowboarding, skiing, mountain climbing, surfing, etc.)
C. Car Accident
D. Other: ____(Explain Briefly)

Did you experience any changes in mental function (i.e. trouble concentrating, remembering things) and/or physical symptoms (i.e. headache, dizziness, fatigue)? Yes No

Was this concussion diagnosed by a medical professional (i.e. doctor, athletic trainer, physician assistant)?

Yes No

Diagnosed Concussion #2

Date of concussion: ________ /________ (approximate month/year)

Circle the option that best describes what you were doing when this concussion was sustained?

A. While playing traditional sports (i.e. football, basketball, soccer, etc.)
B. While participating in extreme sports (i.e., snowboarding, skiing, mountain climbing, surfing, etc.)
C. Car Accident
D. Other: ____(Explain Briefly)

Did you experience any changes in mental function (i.e. trouble concentrating, remembering things) and/or physical symptoms (i.e. headache, dizziness, fatigue)? Yes No

Was this concussion diagnosed by a medical professional (i.e. doctor, athletic trainer, physician assistant)?

Yes No

Diagnosed Concussion #3

Date of concussion: ________ /________ (approximate month/year)

Circle the option that best describes what you were doing when this concussion was sustained?

A. While playing traditional sports (i.e. football, basketball, soccer, etc.)
B. While participating in extreme sports (i.e., snowboarding, skiing, mountain climbing, surfing, etc.)
C. Car Accident
D. Other: ____(Explain Briefly)

Did you experience any changes in mental function (i.e. trouble concentrating, remembering things) and/or physical symptoms (i.e. headache, dizziness, fatigue)? Yes No

Was this concussion diagnosed by a medical professional (i.e. doctor, athletic trainer, physician assistant)?

Yes No

Diagnosed Concussion #4

Date of concussion: ________ /________ (approximate month/year)

Circle the option that best describes what you were doing when this concussion was sustained?

A. While playing traditional sports (i.e. football, basketball, soccer, etc.)
B. While participating in extreme sports (i.e., snowboarding, skiing, mountain climbing, surfing, etc.)
C. Car Accident
D. Other: ____(Explain Briefly)

Did you experience any changes in mental function (i.e. trouble concentrating, remembering things) and/or physical symptoms (i.e. headache, dizziness, fatigue)? Yes No

Was this concussion diagnosed by a medical professional (i.e. doctor, athletic trainer, physician assistant)?

Yes No

19. Have you been diagnosed with 5 or more concussions by a medical professional? (Please circle your selection)

Yes No

If yes, how many total diagnosed concussions have you sustained? (Please place # on line)

____

20. How many additional non-diagnosed concussions do you think you have sustained while playing sports? (Please place # on line)

____

21. How many times have you had your "bell rung", "blacked out", and/or "saw stars" while playing sports? (Please place # on line)

____

Appendix D: Big Five Inventory

I See Myself as Someone Who …

Here are a number of characteristics that may or may not apply to you. For example, do you agree that you are someone who *likes to spend time with others?* Please indicate the extent to which you agree or disagree with each statement using the following scale:
(Please circle your selections)

	I See Myself as Someone Who…	Disagree Strongly	Disagree a Little	Neither Agree nor Disagree	Agree a Little	Strongly Agree
1.	Is talkative.	**1**	**2**	**3**	**4**	**5**
2.	Tends to find fault with others.	**1**	**2**	**3**	**4**	**5**
3.	Does a thorough job.	**1**	**2**	**3**	**4**	**5**
4.	Is depressed, blue.	**1**	**2**	**3**	**4**	**5**
5.	Is original, comes up with new ideas	**1**	**2**	**3**	**4**	**5**
6.	Is reserved.	**1**	**2**	**3**	**4**	**5**
7.	Is helpful and unselfish with others	**1**	**2**	**3**	**4**	**5**
8.	Can be somewhat careless.	**1**	**2**	**3**	**4**	**5**
9.	Is relaxed, handles stress well.	**1**	**2**	**3**	**4**	**5**
10.	Is curious about many different things.	**1**	**2**	**3**	**4**	**5**
11.	Is full of energy.	**1**	**2**	**3**	**4**	**5**
12.	Starts quarrels with others.	**1**	**2**	**3**	**4**	**5**
13.	Is a reliable worker.	**1**	**2**	**3**	**4**	**5**
14.	Can be tense.	**1**	**2**	**3**	**4**	**5**
15.	Is ingenious, a deep thinker.	**1**	**2**	**3**	**4**	**5**
16.	Generates a lot of enthusiasm.	**1**	**2**	**3**	**4**	**5**
17.	Has a forgiving nature.	**1**	**2**	**3**	**4**	**5**
18.	Tends to be disorganized.	**1**	**2**	**3**	**4**	**5**
19.	Worries a lot.	**1**	**2**	**3**	**4**	**5**
20.	Has an active imagination.	**1**	**2**	**3**	**4**	**5**
21.	Tends to be quiet.	**1**	**2**	**3**	**4**	**5**
22.	Is generally trusting.	**1**	**2**	**3**	**4**	**5**
23.	Tends to be lazy.	**1**	**2**	**3**	**4**	**5**
24.	Is emotionally stable, not easily	**1**	**2**	**3**	**4**	**5**

	upset.					
25.	Is inventive.	**1**	**2**	**3**	**4**	**5**
26.	Has an assertive personality.	**1**	**2**	**3**	**4**	**5**
27.	Can be cold and aloof.	**1**	**2**	**3**	**4**	**5**
28.	Perseveres until the task is finished.	**1**	**2**	**3**	**4**	**5**
29.	Can be moody.	**1**	**2**	**3**	**4**	**5**
30.	Values artistic, aesthetic experiences.	**1**	**2**	**3**	**4**	**5**
31.	Is sometimes shy, inhibited.	**1**	**2**	**3**	**4**	**5**
32.	Is considerate and kind to almost everyone.	**1**	**2**	**3**	**4**	**5**
33.	Does things efficiently.	**1**	**2**	**3**	**4**	**5**
34.	Remains calm in tense situations.	**1**	**2**	**3**	**4**	**5**
35.	Prefers work that is routine.	**1**	**2**	**3**	**4**	**5**
36.	Is outgoing, sociable.	**1**	**2**	**3**	**4**	**5**
37.	Is sometimes rude to others.	**1**	**2**	**3**	**4**	**5**
38.	Makes plans and follows through with them.	**1**	**2**	**3**	**4**	**5**
39.	Gets nervous easily.	**1**	**2**	**3**	**4**	**5**
40.	Likes to reflect, play with ideas.	**1**	**2**	**3**	**4**	**5**
41.	Has few artistic interests.	**1**	**2**	**3**	**4**	**5**
42.	Likes to cooperate with others.	**1**	**2**	**3**	**4**	**5**
43.	Is easily distracted.	**1**	**2**	**3**	**4**	**5**
44.	Is sophisticated in art, music, or literature.	**1**	**2**	**3**	**4**	**5**

BFI Personality ***Not included in actual survey.

Neuroticism= 4, 9R, 14, 19, 24R, 29, 34R, 39
Extraversion= 1, 6R, 11, 16, 21R, 26, 31R, 36
Openness to experience= 5, 10, 15, 20, 25, 30, 35R, 40, 41R, 44
Agreeableness= 2R, 7, 12R, 17, 22, 27R, 32, 37R, 42
Conscientiousness= 3, 8R, 13, 18R, 23R, 28, 33, 38, 43R

Appendix E: Barratt Impulsiveness Scale

People differ in the ways they act and think in different situations. This is a test to measure some of the ways in which you act and think. Read each statement and circle the corresponding answer. Do not spend too much time on any statement. Answer quickly and honestly. (Please circle your selections)

		Rarely/ Never	Occasionally	Often	Almost Always/ Always
1.	I plan for job security.	**1**	**2**	**3**	**4**
2.	I act on impulse	**1**	**2**	**3**	**4**
3.	I am restless at lectures or talks.	**1**	**2**	**3**	**4**
4.	I concentrate easily.	**1**	**2**	**3**	**4**
5.	I plan for the future.	**1**	**2**	**3**	**4**
6.	I squirm at plays or lectures.	**1**	**2**	**3**	**4**
7.	I save regularly.	**1**	**2**	**3**	**4**
8.	I plan tasks carefully.	**1**	**2**	**3**	**4**
9.	I act on the spur of the moment.	**1**	**2**	**3**	**4**
10.	I do things without thinking.	**1**	**2**	**3**	**4**
11.	I don't pay attention.	**1**	**2**	**3**	**4**
12.	I say things without thinking.	**1**	**2**	**3**	**4**
13.	I buy things on impulse.	**1**	**2**	**3**	**4**
14.	I am easily bored when solving thought problems.	**1**	**2**	**3**	**4**
15.	I am a careful thinker.	**1**	**2**	**3**	**4**

<u>BIS-15</u>
Non-Planning Impulsivity: 1R, 5R, 7R, 8R, 15R
Motor Impulsivity: 2, 9, 10, 12, 13
Attentional Impulsivity: 3, 4R, 6, 11, 14

***Not included in actual survey.

Appendix F: Brunel Mood Scale

Below is a list of words that describe feelings that people have. Please read each one carefully and circle the answer that best describes how you have felt in the past few weeks. (Please circle your selections)

		Not at all	A little	Moderately	Quite a bit	Extremely
1.	Panicky	**0**	**1**	**2**	**3**	**4**
2.	Lively	**0**	**1**	**2**	**3**	**4**
3.	Confused	**0**	**1**	**2**	**3**	**4**
4.	Worn Out	**0**	**1**	**2**	**3**	**4**
5.	Depressed	**0**	**1**	**2**	**3**	**4**
6.	Downhearted	**0**	**1**	**2**	**3**	**4**
7.	Annoyed	**0**	**1**	**2**	**3**	**4**
8.	Exhausted	**0**	**1**	**2**	**3**	**4**
9.	Mixed-Up	**0**	**1**	**2**	**3**	**4**
10.	Sleepy	**0**	**1**	**2**	**3**	**4**
11.	Bitter	**0**	**1**	**2**	**3**	**4**
12.	Unhappy	**0**	**1**	**2**	**3**	**4**
13.	Anxious	**0**	**1**	**2**	**3**	**4**
14.	Worried	**0**	**1**	**2**	**3**	**4**
15.	Energetic	**0**	**1**	**2**	**3**	**4**
16.	Miserable	**0**	**1**	**2**	**3**	**4**
17.	Muddled	**0**	**1**	**2**	**3**	**4**
18.	Nervous	**0**	**1**	**2**	**3**	**4**
19.	Angry	**0**	**1**	**2**	**3**	**4**
20.	Active	**0**	**1**	**2**	**3**	**4**
21.	Tired	**0**	**1**	**2**	**3**	**4**
22.	Bad Tempered	**0**	**1**	**2**	**3**	**4**
23.	Alert	**0**	**1**	**2**	**3**	**4**
24.	Uncertain	**0**	**1**	**2**	**3**	**4**

BRUMS mood

Anger= 7, 11, 19, 22
Confusion= 3, 9, 17, 24
Depression= 5, 6, 12, 16
Tension= 1, 13, 14, 18
Fatigue= 4, 8, 10, 21
Vigor= 2, 15, 20, 2

***Not included in actual survey.

Appendix G: Brief Sensation Seeking Scale

Please indicate the extent to which you agree or disagree with each item below by choosing a number from 1 to 5, with 1 being that you "Strongly Disagree" and 5 being you "Strongly Agree". (Please circle your selections)

		Strongly Disagree	Disagree	Neither Disagree nor Agree	Agree	Strongly Agree	I do not want to Answer
1.	I would like to explore strange places.	**1**	**2**	**3**	**4**	**5**	**X**
2.	I get restless when I spend too much time at home.	**1**	**2**	**3**	**4**	**5**	**X**
3.	I like to do frightening things.	**1**	**2**	**3**	**4**	**5**	**X**
4.	I like wild parties.	**1**	**2**	**3**	**4**	**5**	**X**
5.	I would like to take off on a trip with no pre-planned routes or timetables.	**1**	**2**	**3**	**4**	**5**	**X**
6.	I prefer friends who are excitingly unpredictable.	**1**	**2**	**3**	**4**	**5**	**X**
7.	I would like to try bungee jumping.	**1**	**2**	**3**	**4**	**5**	**X**
8.	I would love to have new and exciting experiences, even if they are illegal.	**1**	**2**	**3**	**4**	**5**	**X**

***Not included in actual survey.

<u>BSSS</u>
Boredom Susceptibility = 2, 6
Disinhibition = 4, 8
Experience Seeking = 1, 5
Thrill and Adventure Seeking = 3, 7

Appendix H: Michigan State University Institutional Review Board Approval Letter

MICHIGAN STATE
UNIVERSITY

Initial IRB Application Determination *Exempt*

July 22, 2015

To: Tracey Covassin
105 IM Sports Circle

Re: **IRB# x15-769e** Category: Exempt 2
Approval Date: July 22, 2015

Title: Exploring Psychological Variables Between Collegiate Student-Athletes With and Without a History of Sport-Related Concussion

The Institutional Review Board has completed their review of your project. I am pleased to advise you that **your project has been deemed as exempt** in accordance with federal regulations.

The IRB has found that your research project meets the criteria for exempt status and the criteria for the protection of human subjects in exempt research. **Under our exempt policy the Principal Investigator assumes the responsibilities for the protection of human subjects** in this project as outlined in the assurance letter and exempt educational material. The IRB office has received your signed assurance for exempt research. A copy of this signed agreement is appended for your information and records.

Renewals: Exempt protocols do <u>not</u> need to be renewed. If the project is completed, please submit an *Application for Permanent Closure*.

Revisions: Exempt protocols do <u>not</u> require revisions. However, if changes are made to a protocol that may no longer meet the exempt criteria, a new initial application will be required.

Problems: If issues should arise during the conduct of the research, such as unanticipated problems, adverse events, or any problem that may increase the risk to the human subjects and change the category of review, notify the IRB office promptly. Any complaints from participants regarding the risk and benefits of the project must be reported to the IRB.

Follow-up: If your exempt project is not completed and closed after <u>three years</u>, the IRB office will contact you regarding the status of the project and to verify that no changes have occurred that may affect exempt status.

Please use the IRB number listed above on any forms submitted which relate to this project, or on any correspondence with the IRB office.

Good luck in your research. If we can be of further assistance, please contact us at 517-355-2180 or via email at IRB@msu.edu. Thank you for your cooperation.

Sincerely,

Ashir Kumar, M.D.
BIRB Chair

c: Erica Beidler

Office of Regulatory Affairs
Human Research Protection Programs

Biomedical & Health Institutional Review Board (BIRB)

Community Research Institutional Review Board (CRIRB)

Social Science Behavioral/Education Institutional Review Board (SIRB)

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