THE EFFECT OF REPORTED SYMPTOMS AND OTHER FACTORS ON WHETHER HIGH-SCHOOL ATHLETES EXPERIENCE A TYPICAL OR PROLONGED RECOVERY TIME FROM SPORT-RELATED CONCUSSION

By

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DEDICATION PAGE

This dissertation is dedicated to athletic trainers, an integral part of athletics and the healthcare field. Though they may be overlooked and underappreciated sometimes, these healthcare providers are dedicated to the health and safety of people in their care. The long hours, adverse weather conditions, and general stresses associated with the job may deter some. To those athletic trainers who strive daily to protect and improve the physical, mental, and social health of athletes and patients in your care, thank you.

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ABSTRACT

This dissertation consisted of two studies designed to evaluate the symptomology and other factors present at the time of injury and their effects on recovery time of high school athletes who experience sport-related concussion. The first study examined the effect of the number of symptoms reported at the time of sport-related concussion injury on whether high school athletes experience a typical or prolonged recovery time. Within the first study, the total number of symptoms was represented by the number of symptoms that an athlete experienced at the time of injury. Athletes were designated as having a typical recovery time if they experienced symptom recovery within seven days. The prolonged recovery designation was reserved for athletes who took longer than seven days to recover but not more than 28 days to recover. A total of 1,313 cases of high school athletes from over 20 different sports that were included within the study. The average number of symptoms reported at the time of injury was 5.1 ± 2.79. The number of symptoms reported at the time of injury was found to be a significant predictor of a prolonged recovery period (OR 1.26, 95% CI 1.21 – 1.32, $p < 0.001$). These findings indicate that for each additional symptom that an athlete reports at the time of injury, the chances of experiencing a prolonged recovery increases by approximately 26%.

The second study aimed to determine if there were any symptoms or factors present at the time of injury that would predict a prolonged recovery time from sport-related concussion. Athletes were designated as having a typical or prolonged recovery based on the parameters mentioned above. A total of 1,313 cases of sport-related concussions from over 20 different high school sports were included in the study. A total of six symptoms and one other factor were found to be significant predictors of a prolonged recovery period in this high school population. Sex, specifically females, were found to be more likely to experience a prolonged recovery period (OR 0.75, 95% CI 0.57 – 0.97, $p = 0.03$). The six symptoms found to be significant predictors of a prolonged recovery period were: balance issues (OR 1.48, CI 1.14 – 1.93, $p = 0.003$), difficulty concentrating (OR 1.74, CI 1.35 – 2.24, $p < 0.001$), headache (OR 2.20, CI 1.03 – 4.71, $p = 0.042$), insomnia (OR 1.42, CI 1.07 – 1.89, $p = 0.015$), sensitivity to light (OR 1.35, CI 1.02 – 1.80, $p = 0.039$), and sensitivity to noise (OR 1.81, CI 1.35 – 2.42, $p = <0.001$). These findings indicate that high school athletes who report any of these symptoms or who are female may be at an increased risk of experiencing a prolonged recovery period from sport-related concussion. Overall, the findings from each study have implications into the clinical practice of healthcare practitioners who evaluate and care for high school athletes who experience sport-related concussions.

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CHAPTER I

DISSERTATION INTRODUCTION

Sport-related concussion has been thrust to the forefront as a public health issue well over several decades and remains an enigma, both inside and outside of the United States (Kelly, 1999; McCrory et al., 2017). Currently, sport-related concussion is defined as immediate and transient symptoms of a traumatic brain injury (McCrory et al., 2017). Sport-related concussion is caused by a direct blow to the head or a force to the body that is transmitted to the head (McCrory et al., 2017). Thusly, sport-related concussions can occur in athletes of all ages and ability levels while participating in a variety of sport and non-sport related activities. Commonly reported symptoms of sport-related concussions are headaches and dizziness; the intensity of these can range from mild and manageable to severe and debilitating (Lau et al., 2011). Symptoms as a result of a sport-related concussion can last anywhere from 24 hours up to 28 days with the average symptom resolution time occurring at seven days (McCrea, 2003).

The symptomology of sport-related concussion is of the utmost importance to healthcare practitioners and patients, because when assessing a sport-related concussion, the most widely utilized assessment is a subjective report of the patient's symptoms (Broglio et al., 2014; McCrea et al., 2003; McCrory et al., 2017; Notebaert & Guskiewicz, 2005). Even though sport-related concussion assessments typically center around patient reported symptomology, little research has been conducted involving the symptomology of concussion and its relationship to sport-related concussion prognosis (Lau et al., 2011). As a result of the limited amount of research surrounding sport-related concussion symptomology and its effect on sport-related concussion prognosis, further investigation is needed to determine whether sport-related concussion symptomology reported at the time of injury influences the amount of time required to recover from sport-related concussion.

Purpose

Within this dissertation, there were two related, primary purposes each of which will be investigated separately. The first purpose was to determine the extent to which the number of symptoms that a high school athlete reports at the time of injury had an effect on the time in which it takes them to become symptom free. The second purpose of the study was to identify any symptoms or other factors that would indicate a prolonged recovery period following a sport-related concussion. Both of these studies focused on the symptoms and other factors easily assess at the time of injury of sport-related concussion and outcomes related to symptom recovery time.

Research related to the two purposes of this dissertation was somewhat limited, especially in the high school population. As far as the number of symptoms reported predicting a prolonged recovery time is concerned, Lau et al. (2009) found that an increased number of symptoms reported at the time of injury indicates a longer recovery time among high school athletes. Likewise, Kerr et al. (2018) and Schilling et al. (2020) found that a greater number of symptoms reported at the time of injury predicted a recovery time of greater than 28 days in high school aged populations and younger. Zuckerman et al. (2016) discovered a greater number of symptoms reported at the time of injury was a predictor of postconcussion syndrome in collegiate athletes.

When investigating whether or not a certain symptom or other factor present at the time of injury could predict a prolonged recovery time in high school student-athletes, Lau et al. (2011) found that dizziness was a significant predictor of an extended recovery time in a sample of football athletes. Thomas et al. (2018), Kerr et al. (2018), and Schilling et al. (2020) found that females are more likely to experience postconcussion syndrome or a longer recovery time. Other symptoms mentioned in research as potential predictors of a prolonged recovery period or postconcussion syndrome are: amnesia, dizziness, headache, concentration difficulties, insomnia, light sensitivity, recurrent injury, loss of consciousness, and noise sensitivity (Kerr et al., 2017; McCrea et al., 2012; Putukian et al., 2021; Schilling et al., 2020; Zuckerman et al., 2016). One way that this dissertation seeked to improve upon some of the aforementioned studies was by using a larger and more diverse sample size containing multiple sports and both genders all within a high school sample. This dataset contained over 1,300 instances of sport-related concussion, a large sample.

This dissertation expects to show similar results as the current research. Specifically, the first study expected to find that the number of symptoms reported at the time of injury had an effect on an athlete experiencing a prolonged recovery period. The second study hypothesized that some combination of sex, recurrent injury, anterograde amnesia, retrograde amnesia, balance issues, insomnia, light sensitivity, noise sensitivity, and difficulty concentrating would be predictive of a prolonged recovery period.

Study Significance

Determining if the number of sport-related concussion symptoms reported at the time of injury or if a sport-related concussion symptom or other factor present at the time of injury was related to an extended period of time before a high school athlete is symptom free is important. Increased knowledge related to sport-related concussion symptomology and prognosis for return to play are important in regard to the overall safety and academic progress of student-athletes (Bey & Ostick, 2009; Halstead et al., 2013). From an overall safety standpoint, a more accurate prognosis based on symptoms and other factors present at the time of injury would result in a decreased likelihood of an athlete returning to sport too quickly which could result in any number of adverse effects such as second impact syndrome (Bey & Ostick, 2009). From an academic standpoint, a more accurate prognosis based on symptoms and other various factors present at the time of injury would result in a speedier assimilation for a student back into their normal academic routine without as many adverse effects. This improved understanding would also help healthcare practitioners better manage student-athletes' return to play and return to learn with a decreased risk of adverse effects.

This dissertation added to the body of research surrounding sport-related concussion recovery in high school athletes. Thus far, little research has been done in high school athletes across all sports with a sample size as large as the one used in this study. Additionally, little research has been done to differentiate between longer and shorter sport-related concussion recovery times in high school populations.

CHAPTER II

REVIEW OF LITERATURE

Throughout this review of literature, a variety of topics related to sport-related concussion and recovery were examined. Firstly, the current definition of sport-related concussion along with past definitions was reviewed. Additionally, the current etiology of sport-related concussion as well as historical explanations for the etiology of sport-related concussion was examined. The epidemiology of sport-related concussion was also be reported. Lastly, this review will examine sport-related concussion recovery durations as well as factors that affect sport-related concussion recovery, including sex, symptomology, age, and helmet status.

Concussion Definition and Etiology

Roughly once every four years since 2001, the worldwide leading experts in sport-related concussion, the Concussion in Sport Group (CISG), gather to review the latest research and answer questions that are important to clinicians who assess concussion (Aubry et al., 2002; McCrory et al., 2005; McCrory et al., 2009; McCrory et al., 2013; McCrory et al, 2017). One item addressed at each meeting is the best way to define sport-related concussion. The current definition, according to the CISG, is that a sport-related concussion is “a traumatic brain injury induced by a biomechanical forces” (McCrory et al., 2017, p. 839). Furthermore, the CISG points out that sport-related concussion can be caused by a variety of mechanisms that transmit force to the head, signs and symptoms associated with sport-related concussion often represent a functional disturbance as opposed to a structural injury, and that resolution of the signs and symptoms of sport-related concussion will often follow a sequential, linear recovery pattern (McCrory et al., 2017).

As far as the underlying cause of a sport-related concussion is concerned, the term neurometabolic cascade is used to explain the physiological response that occurs in the brain when a person suffers a sport-related concussion. Giza & Hovda (2014) define this physiological response as "a neurometabolic cascade of events that involves bioenergetic challenges, cytoskeletal and axonal alterations, impairments in neurotransmission and vulnerability to delayed cell death and chronic dysfunction" (p. S24). Giza and Hovda (2014) outline some of the ways that a neurometabolic cascade manifests symptoms. According to Giza and Hovda (2014) ionic flux manifests headache as well as light and noise sensitivities. Impaired cognitive function, slower processing speeds, and slower reaction times are attributed to axonal injuries and impaired neurotransmission (Giza & Hovda, 2014).

While there is currently a clearly defined explanation of what a sport-related concussion is and how it occurs, the definition of a sport-related concussion has changed over time as have the theories surrounding what causes them. The history of the interpretation of sport-related concussion was best described by Geoffrey Jefferson (1944) as a "kaleidoscopic panorama" (p. 4330) in which different researchers from various backgrounds and generations attempted to explain and define sport-related concussion utilizing whatever tools and technology were available to them in the area in which they were most familiar. Prior to the 1940's the majority of theories surrounding sport-related concussion focused on vasospasm, vasoparalysis, brain contusions, brain lesions, and changes in intercranial pressure (Jefferson, 1944).

The wide variety of potential explanations could likely be contributed to two prevalent, vastly different definitions of what was then referred to as cerebral concussion. One of these popular definitions of cerebral concussions was “an unconscious state after head injury unassociated with macroscopic or microscopic lesions of the brain” (Gurdjan, Webster, & Arnkoff, 1943, p. 352). Obviously, based on this definition, an individual would have to receive head trauma severe enough to render them unconscious before being identified as a person with a case of a cerebral concussion. On the other hand, Denny-Brown & Russell (1941) noted that cerebral concussion can occur without any specific structural injury to head or brain. Within that same study, Denny-Brown & Russell (1941) also sought to establish the minimal stimulus required to cause brain dysfunction.

Based on Denny-Brown & Russell’s (1941) quest to establish a minimum stimulus of cerebral concussion and their belief that cerebral concussion could occur without a detectable pathology, it is clear that they believed cerebral concussion could occur without a loss of consciousness or without physical damage to the brain. Jefferson (1944) supported this belief by noting that the primary cause of cerebral concussion is a “paralytic effect” (p. 2) on the neurons and that cerebral concussion is a “functional disorder” (p. 4). Jefferson (1944) highlighted this idea by mentioning that brain dysfunction, or a change in activity, does not always have to accompany a gross, physical change. These are two of the earliest examples of researchers establishing the notion that brain dysfunction does not have to be accompanied by physical damage, a notion that is reflected in the most current definition of sport-related concussion.

Researchers moved forward based on the notion that a cerebral concussion was the result of brain dysfunction. Ward (1964) defined cerebral concussion as “the loss consciousness and associated traumatic amnesia which occurs as the consequence of head trauma in the absence of physical damage to the brain” (p. 95). Other researchers at that time, reflected similar definitions of cerebral concussion, but added a layer to the definition surrounding the transiency of signs and symptoms (Committee to Study Head Injury Nomenclature, 1966; Symonds, 1962). One such group defined concussion as “a clinical syndrome characterized by immediate and transient impairment of neural function” (Committee to Study Head Injury Nomenclature, 1966, p. 386). Symonds (1962) agreed with the transiency of symptoms including “prolonged disturbance of consciousness and the presence of residual symptoms” (p. 1) into his definition of cerebral concussion.

While many researchers seemed to be narrowing down a definition of cerebral concussion during this time, there was disagreement in certain aspects of defining cerebral concussion. Symonds (1962) was of the opinion that cerebral concussion should not just include those cases in which recovery is quick and immediate. Other researchers supported this claim, agreeing that cerebral concussion could potentially include a variety of levels based on the extent to which the patient is impaired (Walker, 1973).

Along these same lines, researchers began to address the varying degrees of severity of sport-related concussion. One of the earliest attempts at stratifying sport-related concussion came from Ommaya and Gennarelli (1974) in an article in which they stratified all cerebral concussions ranging from confusion to coma and death. They defined sport-related concussion as “a graded set of clinical syndromes following head injury wherein increasing severity of disturbance in level and content of consciousness is caused by mechanically induced strains affecting the brain" (Ommaya & Gennarelli, 1974, p.637). This definition alludes to the six varying levels of sport-related concussion set forth in their study. Moving forward, the push to establish a uniform set of guidelines to classify and treat sport-related concussion would be fueled by the number of injuries occurring in sports.

During the 1970's decade, roughly 12 deaths per year, 1 death per 100,000, occurred to student athletes participating in high school football (Kucera et al., 2015). Gerberich et al. (1983) made a profound statement that summarized the directions that sport-related concussion research would go moving forward:

> A finding of this many concussion episodes, together with the way they were handled, suggests problems of defining and understanding concussion and differences in diagnosis and diagnostic criteria by medical personnel or other individuals presumably trained in injury assessment. The hesitancy of the player to reveal physical symptoms that might result in restriction of his activity further complicates identification. (p. 1373)

Within the quote, there are a few issues pointed out by the authors. Firstly, sport-related concussions were occurring at a significant rate. This will be evaluated in depth. Secondly, there was an issue with a lack of clarity on how sport-related concussions were defined. Even though research had been performed previously, there was not yet an agreed upon widely accepted definition of sport-related concussion. Lastly, the authors mention diagnostic criteria, differences in diagnosis, and the availability of trained healthcare practitioners to assess these injuries. The diagnostic criteria and difference in diagnosis is an allusion to the need for a sport-related concussion grading scale to guide medical personnel in both the diagnosis of sport-related concussion as well as management of the injury and safe return to activity.

To fill the void of a lack of sport-related concussion grading systems, Dr. Robert Cantu, the Colorado Medical Society, and the American Academy of Neurology all set forth guidelines to classify sport-related concussions and return to play with the development of sport-related concussion grading scales (American Academy of Neurology, 1997; Cantu, 1992; Colorado Medical Society, 1991). With all three scales, sport-related concussions were graded one through three with grade three being the most severe; additionally, all three scales contained return to play guidelines based on each of the three grades (American Academy of Neurology, 1997; Cantu, 1992; Colorado Medical Society, 1991). Other similarities between the three scales are that each of the three have a relatively strict return to play status for each grade (i.e. an athlete may return to play in 2 weeks if asymptomatic at rest and exertion for 7 days); there are various similarities and differences among the three scales (American Academy of Neurology, 1997; Cantu, 1992; Colorado Medical Society, 1991).

While a sport-related concussion grading scale and a standard guide that would clearly define a safe timeframe for return to play would be useful, the sport-related concussion grading scales proved to be little more than a rough guide that recommended inappropriate action more often than not. According to the first two consensus statements the International Conference of Concussion in Sport, various sport-related concussion grading scales have both strengths and weaknesses, but no grading scale was endorsed (Aubry et al., 2002; McCrory et al., 2005). The first International Conference of Concussion in Sport recommended "combined measures of recovery should be used to assess injury severity and hence individually guide decisions on return to play" (Aubry et al., 2002, p. 7).

The latest International Conference of Concussion in Sport recommends a multidimensional evaluation that includes a "comprehensive history and detailed neurological examination including a thorough assessment of mental status, cognitive functioning, sleep/wake disturbance, ocular function, vestibular function, gait, and balance" (p. 841) while paying special attention to whether or not the patient has had improvement or deterioration following the injury (McCrory et al., 2017). While the use of a multidimensional assessment tool is recommended, the use of a symptom checklist and symptom scores demonstrates a "clinical utility in tracking recovery" (McCrory et al., 2017, p. 840). Furthermore, in regard to symptomology, McCrory et al. (2017) notes that "baseline testing may be useful but is not necessary for interpreting post-injury scores" (p. 840). Thus, symptomology following sport-related concussion is one of the few assessment tools that does not require baseline testing to be an effective evaluation strategy.

This review will examine the literature related to recovery differences between young and older age groups. Differences in sport-related concussion severity and length of time taken to recover between ages are attributed to a few different things. One of those differences is the size of head relative to the neck strength and body size of the individual (Goldsmith & Plunkett, 2004). Additionally, differences in the vascularity of the brain and degree of myelination may attribute to differences in recovery patterns between age groups (Bauer & Fritz, 2004). Lastly, brains that are younger are going through development and respond to injury differently from a physiological standpoint (Giza & Hovda, 2001).

Epidemiology of Concussion

Many studies performed in relation to sport-related concussion focus on collegiate or professional athletes, however a substantially lower number of studies have been done involving the high school population (Gessel et al., 2007; Prien et al., 2018). In addition to a significantly larger number of athletes who play high school sports as opposed to college sports, the percentage of sport-related concussion to total injuries is higher in high school athletes as opposed to college athletes (Gessel et al., 2007). Between 9% and 15% of all injuries involving high school athletes are sport-related concussion (Gessel et al., 2007; Meehan et al., 2011). Similarly, Marar et al. (2012) reported 13.2% of all sports related injuries in high school athletes are sport-related concussion. Likewise, Castile et al. (2012) reported 10.5% of all sports related injuries in high school athletes are sport-related concussion. Comparatively, Gessel et al. (2007) reported only 5.8% of sports related injuries that occurred in collegiate athletes were sport-related concussion. This shows a larger percentage of injury being sport-related concussion in high school athletes compared to collegiate athletes.

There are a variety of factors that may play a role whether or not an athlete suffers a sport-related concussion. Some of the most relevant factors that play a role in the likelihood of an athlete suffering a sport-related concussion are the sport in which he or she plays, sex, and history of sport-related concussion. As one would imagine, the sport in which an athlete participates is a predictor of whether or not he or she would suffer a sport-related concussion. As many people would expect, collision and contact sports, like football, hockey, and soccer, contain the highest rates of sport-related concussion while non-contact or non-collision sports, like track and field, tennis, and golf, have the lowest rates of sport-related concussion (Guskiewicz et al., 2000; Meehan et al., 2011; Meehan et al., 2011; O'Conner et al., 2017). Athletes with a history of sport-related concussion are more likely to suffer another (Guskiewicz et al., 2000; Lincoln et al., 2011; O'Conner et al., 2017; Tsushima et al., 2019). Females are more likely to suffer a sport-related concussion than males (Guskiewicz et al., 2000; Lincoln et al., 2011; O'Conner et al., 2017).

In regard to sport, there are trends in research related to the rate of injury of sport-related concussion. As many would expect, football consistently had a higher rate of injury than other sports. O'Conner et al. (2017) reported 9.21 concussions per 10,000 athlete exposures for high school football players compared to 3.89 per 10,000 athlete exposures across all high school athletes. Castile et al. (2012) also reported the highest number of sport-related concussion occurring with football at a rate of 53.9 per 100,000 athlete exposures; for context, the next second highest rate of exposure in that study was 29.8 per 100,000 athlete exposures which was recorded from girls' soccer. Marar et al. (2012) reported 47.1% of the sport-related concussion in the sample were from football. Football being the sport with the highest incidence rate of sport-related concussion was consistent across all studies reviewed with the exception of a study done by Chun et al. (2021) in which girls martial arts had more concussions per athlete exposure than did football or any other sport studied.

As far as female sports were concerned, girls' soccer was consistently the female sport with the highest rate of sport-related concussion. O'Conner et al. (2017) reported a rate of 6.11 sport-related concussions per 10,000 athlete exposures. Castile et al. (2012) reported 29.8 sport-related concussions per 100,000 athlete exposures, second only to football. In both examples, girls' soccer was the female dominant sport with the highest rate of sport-related concussion. One of the only studies that contained multiple sports in which girls' soccer was not the highest rate of sport-related concussion for a female dominated sport was a study done by Chun et al. (2021) in which girls' martial arts had a greater number of sport-related concussion per athlete exposure than did any other sport.

Other sports with seemingly high rates of sport-related concussion were collision or contact sports. Within the studies reviewed, lacrosse appeared as one of the top three highest rates of sport-related concussion in two of the studies at 0.3 sports related concussion per 1,000 athlete exposures compared to football at 0.6 and at 6.65 sport-related concussion per 10,000 athlete exposures compared to football at 9.21 (Lincoln et al., 2011; O'Conner et al. 2017). Likewise, wrestling appeared as one of the top three highest rates of sport-related concussion in two of the studies at 1.14 sport-related concussion per 1,000 athlete exposures and 18.1 per 100,000 athlete exposures (Castile et al., 2012; Putukian et al. 2019). Other sports whose rate of sport-related concussion was higher than average within the literature was boys soccer, girls basketball and martial arts (Castile et al., 2012; Chun et al. 2021; Marar et al., 2011; O'Conner et al., 2017). As previously mentioned, collision and contact sports show higher rates of sport-related concussion than non-contact and non-collision sports.

Besides a higher risk of sport-related concussion from sport, athletes are statistically more likely to suffer a sport-related concussion during competition as opposed to suffering the injury during practice. O'Conner et al. (2017) reported 6.78

sport-related concussion per 10,000 athlete exposures during football practice compared to 19.87 sport-related concussion per 10,000 athlete exposures during football competition. Marar et al. (2012) reported 66.6% of sport-related concussions occurring during competition at a rate of 6.4 per 10,000 athlete exposures compared to 33.4% of sport-related concussions occurring during practice at a rate of 1.1 sport-related concussions per 10,000 athlete exposures. Marar et al. (2012) reported 19 of the 20 sports included in the study suffered more sport-related concussions during competition than practice; of those 19 sports, 13 of them suffered significantly more sport-related concussions during competition than practice.

Females are more at risk of suffering a sport-related concussion than males (Chun et al., 2021; Lincoln etl al., 2011; O'Conner et al., 2017). Lincoln et al. (2011) reported significantly more sport-related concussions in females than males in the following comparable sports: basketball, soccer, and baseball/softball. O'Conner et al. (2017) reported similar results with females suffering significantly more sport-related concussions than males in baseball/softball, soccer, basketball and indoor track. Chun et al. (2021) reported significantly more sport-related concussions in females than males in martial arts, soccer, basketball, and baseball/softball.

Aside from the sport than an athlete competes in and gender, an athlete's history of sport-related concussion plays a role in recovery time and increases the likelihood of an athletes suffering a concussion (Chrisman et al., 2019; Guskiewicz et al., 2000; Tsushima et al., 2019). Guskiewicz et al. (2000) found that football athletes who suffer a concussion have roughly a 15% chance of suffering a second sport-related concussion during that same season. Chrisman et al. (2019) also reported a history of prior sport-related concussion as a significant predictor of suffering an additional sport-related concussion. This is elevated from the 5.6% chance that football athletes have of sport-related concussion without injury history (Guskiewicz et al., 2000). Meehan et al. (2011) reported 11.6% of sport-related concussions are recurrent. Tshushima et al. (2019) reported athletes with a history of one and two or more sport-related concussions have an increased risk of suffering additional sport-related concussion with adjusted risk ratios of 5.07 and 4.34, respectively.

Concussion Recovery

While epidemiology of sport-related concussion may slightly differ between high school and collegiate athletes, recovery from a sport-related concussion typically follows a linear and sequential pattern until the athlete returns to his or her pre-injured state regardless of age (McCrory et al., 2017). Therefore, a topic that is often addressed in research and is often of high importance to clinicians is how long recovery should take for injured athletes. Symptom score, or total symptom score, is a number that represents the severity of each symptom on a Likert-type scale and a total of those numbers present at the time of evaluation.

From an evaluation perspective, athlete-reported symptoms are the most commonly utilized tool for the assessment and management of a sport-related concussion (Broglio et al., 2014; McCrea et al., 2003; McCrory et al., 2017). Even though the use of symptomology is subjective in nature, the use of athlete-reported symptoms for the assessment of sport-related concussion was deemed acceptable from both a sensitivity and reliability standpoint by McCrea et al. (2005) and Broglio et al. (2008). McCrea et al. (2005) reported specificity of 1.0 from the time of injury up through day 7 post injury;

the same study reported sensitivity of 0.89 at the time of injury ranging to 0.04 at 7 days post injury. Within the study, the sensitivity numbers decreased at a relatively constant rate, 0.53 at one day post injury, 0.27 at two days post injury, 0.1 at 5 days post injury (McCrea et al., 2005). Broglio et al. (2008) reported a sensitivity of 0.68 within 24 hours of the initial injury.

Examining the change in symptom score from baseline or from the date of injury helps practitioners understand the total effect that sport-related concussions are having on the affected athletes. Most of the graded symptom checklists contain a seven-point Likert scale for each symptom with severities ranging from zero through six with six being the most severe symptom (Linder et al., 2021; Lovell et al., 2003; McCrea et al., 2005; McCrea et al., 2012; Meehan et al., 2014; Teel et al., 2017). Other symptom checklists contain a binary answer for each symptom with the two choices being yes the symptom is present or no the symptom is not present (Kerr et al., 2018; O'Conner et al., 2017).

While the scales on the symptom checklists are relatively similar across the research, there is variance as to the symptoms on each checklist. Some studies utilize 17 different symptoms on the checklist (Kerr et al., 2018; McCrea et al., 2005; O'Conner et al., 2017; Teel et al., 2017). Other studies utilize a checklist with a range of 21 through 27 symptoms (Linder et al., 2021; Lovell et al., 2003; McCrea et al., 2012; Meehan et al., 2014). The international consensus statement on concussion in sport recommends the use of a symptom checklist in the evaluation of sport-related concussions; however, no specific list of symptoms is recommended (McCrory et al., 2017). This may explain the variance as seen with the symptoms that are present on the symptom checklists.

As far as scores on graded symptom checklists are concerned, baseline scores, scores before any injury has occurred, will typically be lower with a sharp increase in symptom score just after injury and a steady decrease in symptom score over time after the injury has occurred (Teel et al., 2017). Baseline graded symptom checklist scores can range from 0.99 through 4.23 across various studies and groups within the studies (McCrea et al., 2005; McCrea et al., 2012). Keep in mind, some of the variation seen in the baseline scores could be present as a result of the different numbers of symptoms present on the scale. In the two aforementioned studies, McCrea et al. (2005) utilized a 17-symptom score and reported a low mean baseline score of 0.99 out of a possible 102. McCrea et al. (2012) utilized a 25-symptom checklist and reported a mean baseline score of 4.23 out of a possible 150.

As expected, symptom scores from graded symptom checklists will greatly increase just after injury and decrease over time afterward. McCrea et al. (2005) reported a grade symptom checklist score of 20.60, out of a maximum score of 102, at the time of injury decreasing to 16.73 after the game or practice in which the injury occurred. Along those same lines, McCrea et al. (2003) reported a graded symptom checklist score of 20.97, out of a maximum of 102, at the time of injury decreasing to 16.97 after the game or practice in which the injury occurred. At 24 hours post injury and 48 hours post injury, McCrea et al. (2003) reported graded symptom checklist scores of 11.53 and 6.88, respectively. These scores were similar to the McCrea et al. (2005) 24 and 48 hours post injury graded symptom checklist scores of 12.25 and 7.63, respectively. Lovell et al. (2003) echoed similar findings with a 36 hours post injury graded symptom checklist score of 9.9. McCrea et al. (2005) as well as McCrea et al. (2003) both reported graded symptom checklist scores below baseline by day seven following an injury. Though most studies utilize the mean graded symptom checklist scores, Linder et al. (2021) utilized median scores due to skewed data in the sample; it was hypothesized that the skewed data was a result of a few subjects possessing very high graded symptom checklist scores while the majority of subjects had little to no symptoms present.

McCrea et al. (2012) reported seven days as a typical recovery window based on consistent reports found throughout the literature; this finding was confirmed based upon the symptom change score within the same study. Also within McCrea et al. (2012) study, 90% of athletes with sport-related concussion fell into the typical category and 10% fell into the prolonged recovery time category. Lovell et al. (2003) reported no significant difference in symptom scores at days four and seven during recovery but did find memory deficits at those times which would indicate recovery had not occurred.

As far as recovery is concerned, some studies have noted a more protracted recovery time for high school athletes compared to collegiate athletes. Field et al. (2003) noted an abrupt increase in sport-related concussions symptoms in both collegiate and high school athletes that slowly declined in severity from the time of injury until day seven, but when compared to controls, high school athlete's symptom severity was significantly different through day seven while collegiate athletes were only significantly different from controls until day three. Along the same lines, the 3rd International Conference of Concussion in Sport states that an athlete's age of less than 18 years old represents a modifying factor that may predict a prolonged recovery (McCrory et al., 2009). Similarly, Field et al. (2003) found cognitive differences between collegiate athletes and controls up to 3 days post injury, whereas cognitive differences between high school athletes and controls occurred up to 7 days post injury. Likewise, Nelson et al. (2016) found cognitive recovery from sport-related concussion to occur more quickly in high school athletes than collegiate ones. Conversely Lee et al. (2013), found no statistically significant differences of recovery to symptom baseline between younger and older athletes. Some of the differences in research on the topic of high school versus college recovery time with concussion may be explained by Williams et al. (2015). Within that meta-analysis, Williams et al. (2015) discovered that symptom recovery was significantly more variable in high school athletes compared to their college counterparts.

For the most part, it is accepted that high school athletes recover from sport-related concussion slower than collegiate athletes, yet the sequential, linear recovery alluded to by McCrory et al. (2017) holds true throughout the literature. McCrea et al. (2012) investigated differences in athletes with prolonged and typical recovery patterns. While the recovery time was different between the two groups, a linear and sequential recovery pattern was noted for cognitive, symptom, and balance testing. McCrea et al. (2003) reported similar findings in regard to recovery following sport-related concussion. Lovell et al. (2003) investigated recovery patterns of both mild and severe sport-related concussion which echoed the sentiment of a linear recovery pattern for both mild and severe concussions. McCrea et al. (2005) investigated recovery patterns of postural control, symptoms, and cognitive impairment in collegiate athletes illustrating the linear and sequential recovery patterns in graphs at assessment points at the time of injury, post-practice/game, and at days one, two, three, five, and seven. For all three, the greatest amount of impairment occurred at the time of injury and the least amount of impairment occurring at the assessment seven days after the initial injury. Nelson et al. (2016)

conducted a similar study involving both high school and collegiate athletes. Within the study, high school and collegiate athletes had a similar recovery pattern for symptom recovery, cognitive recovery, and recovery of postural control. These studies all illustrate linear recovery following concussion from the standpoints of cognition, symptomology, and postural stability (Nelson et al., 2016).

While up to seven days is regarded as a typical time for recovery from sport-related concussion, the onset of postconcussion syndrome would set an upper limit of the recovery time following sport-related concussion. Thus, after three or more symptoms have persisted past the 28-day mark, the International Classification of Diseases, 10^{th} Edition (ICD 10) would classify the patient as having postconcussion syndrome. Similarly, Rose, Fischer, and Heyer (2015) report a diagnosis of postconcussion syndrome if a patient presents with a single sport-related concussion symptom more than 28 days after a head injury; this definition is based on a survey of over 500 doctors. Therefore, any athlete reporting symptoms after 28 days would be categorized as having postconcussion syndrome, especially if that athlete was reporting multiple symptoms.

It is important to rule out postconcussion syndrome cases from research of concussions. Both Linder et al. (2021) and McCrea et al. (2012) mention the potential for skewed data as a result of athletes who would be classified as having postconcussion syndrome. McCrea et al. (2012) reported some study participants with elevated symptom scores all the way up to days 45 and 90 post injury which skewed the data within the study reported. Likewise, Linder et al. (2021) echoed a similar sentiment reporting a small number of study participants who had reported the highest symptom scores skewing his findings. This along with the definition of postconcussion syndrome in the

ICD 10 would indicate the need for researchers to exclude athletes who would be diagnosed with postconcussion syndrome from any analysis of sport-related concussion.

In addition to a sport-related concussion history increasing the likelihood of suffering another sport-related concussion, some studies have illustrated more severe symptoms or a longer recovery time for athletes who have a history of sport-related concussion. Nelson et al. (2016) concluded that one of the few predictive variables of an increased symptom score following sport-related concussion is a history of sport-related concussion. As previously mentioned in the literature review, a high symptom score at the time of injury often results in increased symptom resolution time and recovery. Castile et al. (2012) reported light and noise sensitivity being reported more often in recurrent sports related sport-related concussion. The same study reported athletes with recurrent sport-related concussion took significantly longer to return to play.

Although some sports are more likely to experience more sport-related concussion than others, a larger quantity does not necessarily mean that the severity and time that it takes for recovery is longer. However, this can be the case. In a study by Kerr et al. (2018), football, which is the sport with the largest quantities of sport-related concussion, also contained a significantly greater number of sport-related concussions that resulted in postconcussion syndrome. The study also showed, when sports were grouped together into categories, collision, contact, and non-contact, there were significantly greater numbers of postconcussion syndrome cases in the collision and contact sport groups (Kerr et al., 2018). While this study seeks to examine differences between a prolonged and typical recovery time, it is not a stretch to hypothesize that a greater number of athletes would suffer prolonged recovery times in those collision and contact sports.

Both Kerr et al. (2018) and Zuckerman et al. (2016) both investigated the use of helmets in sport as a predictor of postconcussion syndrome. Essentially, this is a simplification of the type of sport played, however instead of dividing sports based on contact level, sports are defined as whether most of the team wears a helmet during all or part of the gameplay. Both aforementioned studies did not find any significance of helmet status. But since there is evidence of different types of sports having longer recovery times, helmet status will be included as a predictor variable in this investigation.

Sex also plays a role in the likelihood that an athlete will sustain a sport-related concussion. Although sport and sex are dependent upon one another, females sustain sport-related concussions at a higher rate. O’Conner et al. (2017) reports males sustaining sport-related concussion at a rate of 1.69 per 10,000 exposures whereas females sustain sport-related concussion at a rate of 2.64 per 10,000 exposures. As far as symptomology and symptom severity between sexes is concerned, there are conflicting reports. While examining postconcussion syndrome in collegiate student athletes Zuckerman et al. (2016) did not find sex as a significant predictor of postconcussion syndrome. However, in a population of high school student athletes or younger, Kerr et al. (2018), Schilling et al. (2020), and Thomas et al. (2018) all found sex to be a significant predictor of postconcussion syndrome or a longer recovery period.

One of the purposes of this dissertation was to determine if the number of symptoms reported at the time of injury would be a predictor of a prolonged recovery period from sport-related concussion. Based on the research, it was hypothesized that a greater number of symptoms reported at the time of injury would predict a prolonged recovery period. The other purpose of this dissertation was to examine if there is a symptom or other factor present at the time of injury that predicted a prolonged recovery time from sport-related concussion. There are various that may indicate a longer recovery time. McCrea et al. (2012) reported loss of consciousness, retrograde amnesia, and posttraumatic amnesia as symptoms which could lead to a prolonged recovery. Kerr et al. (2018) found that high school athletes who present with retrograde amnesia, difficulty concentrating, disorientation, insomnia, noise sensitivity, and visual disturbance have increased odds of postconcussion syndrome. Zuckerman et al. (2016) also found that collegiate athletes who report amnesia, difficulty concentrating, dizziness, irritability, vomiting, insomnia, drowsiness, loss of balance, sensitivity to light, and sensitivity to sound have increased odds of postconcussion syndrome. Similarly, Schilling et al. (2020) reported retrograde and anterograde amnesia at the time of injury were indicative of a prolonged recovery time. Based on the available research, it was hypothesized that some combination of sex, recurrent injury, anterograde amnesia, retrograde amnesia, balance issues, insomnia, light sensitivity, noise sensitivity, and difficulty concentrating would be predictors of a prolonged recovery period.

CHAPTER III

NUMBER OF REPORTED SYMPTOMS AND THE EFFECT ON RECOVERY TIME FROM SPORT-RELATED CONCUSSION IN HIGH-SCHOOL ATHLETES

Sport-related concussion is a public health issue that has been plaguing athletes of various competition levels worldwide (Kelly, 1999; McCrory et al., 2017). A sport-related concussion is defined as "representing the immediate and transient symptoms of a traumatic brain injury (TBI)" (McCrory et al., 2017, p. 839). Sport-related concussions are caused by a direct force to the head or a force that is indirectly applied to the head (McCrory et al., 2017). As a result, sport-related concussion can occur in athletes of all ages, ability levels, and during a variety of sport and non-sport related activities.

When assessing a sport-related concussion, the most widely utilized assessment is patient reported symptoms (Broglio et al., 2014; McCrea et al., 2003; McCrory et al., 2017; Notebaert & Guskiewicz, 2005). McCrea et al. (2012) used symptom recovery time to stratify athletes into varying recovery patterns. The justification and reasoning for using symptom recovery time was due to the fact that researchers "were interested in the indicator relied on most in the setting of clinicians determining an athlete's overall clinical recovery and fitness to return to play" (McCrea et al., 2012, p. 3). Even though sport-related concussion assessments typically center around patient reported symptomology, little research has been performed surrounding symptomology of sport-related concussion and prognosis of recovery in high school aged athletes (Lau et al., 2011). Literature on the number of symptoms reported and extended recovery time from sport-related concussion is somewhat limited.

Some studies seek to differentiate between a typical recovery time and postconcussion syndrome or a typical recovery time and a recovery period of greater than 28 days (Kerr et al., 2018; Meehan et al., 2014; Schilling et al., 2020; Zuckerman et al., 2016). Both Kerr et al. (2018) and Zuckerman et al. (2016) found that the number of symptoms reported at the time of injury was a significant predictor of whether or not athletes would be diagnosed with postconcussion syndrome in high school athletes and collegiate athletes, respectively. Within those two studies, any athlete who reported having at least one symptom for a minimum of four weeks or 28 days was categorized as having postconcussion syndrome. Schilling et al. (2020) and Meehan et al. (2014) found that the number of symptoms reported by athletes suffering a sports related concussion was a significant predictor of a prolonged recovery period in patients under the age of 18. In the Schilling et al. (2020) and Meehan et al. (2014) studies, a prolonged recovery period was defined as 28 days or more.

While the aforementioned studies all examined predictors of recovery period of greater than 28 days, Thomas et al. (2018) evaluated the effect of symptoms reported on recovery time in general. Within this study, Thomas et al. (2018) discovered that as recovery time, on a week-by-week basis, increased as total symptom burden at the time of injury increased. This study utilized a sample of patients under the age of 18 (Thomas et al., 2018).

As noted above, some research examines symptoms as predictors of a recovery time of greater than 28 days or postconcussion syndrome (Kerr et al., 2018; Meehan et al., 2014; Schilling et al., 2020; Zuckerman et al., 2016). This study seeks to differentiate between a typical and prolonged recovery time. McCrea et al. (2012) reported symptom resolution at or before seven days post injury as a typical recovery time. Therefore, participants in this study whose symptoms resolve at or before 7 days are stratified into the typical recovery group. A sport-related concussion symptom or group of symptoms lasting longer than 28 days has been characterized as postconcussion syndrome (Zuckerman et al., 2016; Kerr et al., 2018). Therefore, participants whose symptoms resolve after 28 days are excluded from the analysis. Lastly, athletes whose sport-related concussion symptoms resolve after seven days but not longer than 28 days will be stratified into the prolonged recovery group.

The purpose of this study was to examine whether the number of symptoms reported at the time of injury was predictive of an athlete experiencing a prolonged recovery period from sport-related concussion. It was hypothesized that a greater number of symptoms reported at the time of injury would be a predictor of a longer recovery period from sport-related concussion.

Methods

The National Athletic Treatment, Injury and Outcomes Network (NATION) is an injury surveillance program that aims to collect data related to injuries sustained by high school student athletes. All injuries were evaluated and reported by certified athletic trainers working at both practices and competitions; athletic trainers reported injuries from 27 different sports in 147 high schools across 26 different states from the 2011 to 2014 school years (Dompier et al., 2015). According to Kerr et al. (2018), 84.4% of these high schools were public, 98.6% were coeducational, 75.5% were in non-urban areas, and 51.0% had enrollments of less than 1,000 students.

Data were recorded from a variety of different electronic medical record programs using a common data element export standard, which essentially collects data from the electronic injury reporting software already being used by athletic trainers (Dompier et al., 2015). Both automated and manual quality control checks of data were completed at the Datalys Center (Dompier et al., 2015). There was an assortment of data that was collected. The items pertinent to this study are a detailed injury report containing dichotomous (yes/no) items for 17 different symptoms associated with concussion, a dichotomous (yes/no) item indicating whether or not the injury is a concussion, and a categorical variable related to when all concussion symptoms resolved.

Data Analysis

Data was analyzed to describe the athletes in the typical and prolonged recovery groups. Continuous variables were described using means and standard deviations. Categorical data were presented as percentages of the total population included in the analysis. Odds ratios and confidence intervals were estimated using logistic regression. The independent variable in this analysis was the number of symptoms that the athlete presented with at the initial injury. The dependent variable will be the dichotomized variable of concussion symptom resolution time, typical recovery or prolonged recovery. The method of dichotomizing the concussion symptom resolution time variable is described above. Data were analyzed using Statistical Package for Social Sciences (SPSS) (version 28.0).

Results

Within the study, 1,313 subjects had no missing data points and were included in the analysis. Descriptive statistics of the sample are reported in Table 1. Within the study, 73.6% of the population was male, and 26.4% was female. Of the sample, freshman represented 37.8%, sophomores were 26.5%, juniors were 19.5%, and seniors were 17.1% of the population. Football players represented the largest portion of the sample and the most represented male sport, 51.6% of the population. Girls' basketball represented the second largest group and the most represented female sport, 6.7% of the population.

Table 1

Descriptive Statistics of Participant Demographic Information and Recovery Period

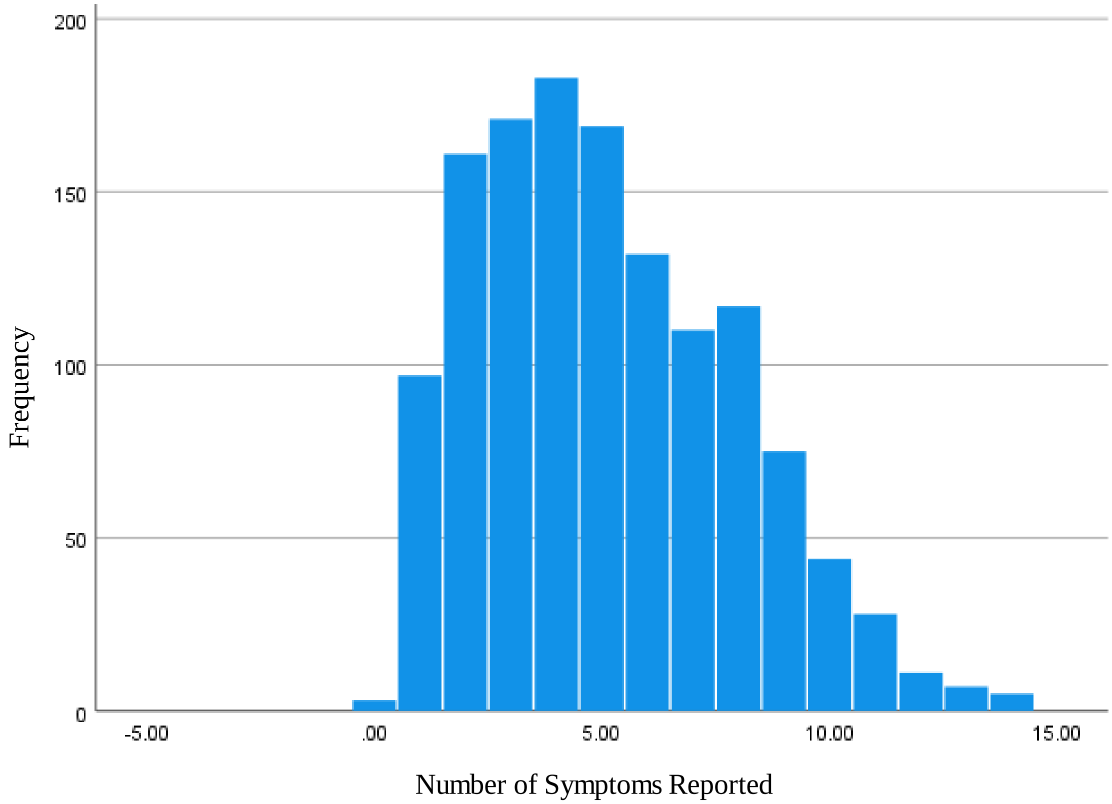
Characteristic	Total	Typical Recovery	Prolonged Recovery
Sex (no. [%])			
Male	967 (73.6)	540 (41.2)	427 (32.5)
Female	346 (26.4)	163 (12.4)	183 (13.9)
Grade Level (no. [%])			
Freshman	496 (37.8)	273 (20.8)	223 (17.0)
Sophomore	336 (25.6)	168 (12.8)	168 (12.8)
Junior	257 (19.5)	127 (9.7)	130 (9.8)
Senior	224 (17.1)	135 (10.3)	89 (6.8)
Sport (no. [%])			
Boys Football	678 (51.6)	360 (28.9)	298 (22.7)
Girls Basketball	87 (6.7)	44 (3.4)	43 (3.3)
Boys Lacrosse	78 (5.9)	44 (3.3)	34 (2.6)
Boys Wrestling	73 (5.6)	43 (3.3)	30 (2.3)
Girls Soccer	71 (5.4)	28 (2.1)	43 (3.3)
Boys Basketball	61 (4.6)	34 (2.6)	27 (2.1)
Boys Soccer	60 (4.5)	31 (2.3)	29 (2.2)
Girls Volleyball	51 (3.9)	31 (2.4)	20 (1.5)
Girls Field Hockey	39 (3.0)	21 (1.6)	18 (1.4)
Girls Lacrosse	38 (2.8)	14 (1.1)	24 (1.7)
Girls Softball	34 (2.5)	16 (1.2)	18 (1.3)

Characteristic	Total	Typical Recovery	Prolonged Recovery
Boys Baseball	10 (0.8)	5 (0.7)	5 (0.7)
Girls Swim/Dive	5 (0.4)	4 (0.3)	1 (0.1)
Boys Outdoor Track	5 (0.4)	2 (0.1)	3 (0.3)
Girls Outdoor Track	5 (0.4)	1 (0.1)	4 (0.3)
Girls Tennis	4 (0.4)	1 (0.1)	3 (0.3)
Girls Cross Country	3 (0.2)	0 (0.0)	3 (0.2)
Boys Swim/Dive	3 (0.2)	1 (0.1)	2 (0.2)
Girls Gymnastic	3 (0.2)	1 (0.1)	2 (0.2)
Boys Indoor Track	2 (0.2)	0 (0.0)	2 (0.2)
Girls Indoor Track	2 (0.2)	2 (0.2)	0 (0.0)
Girls Rowing	1 (0.1)	0 (0.0)	1 (0.1)

The average number of symptoms reported was 5.1 ± 2.79. The 703 athletes in the typical recovery group reported an average of 4.3 ± 2.55 symptoms. The 610 athletes in the prolonged recovery group reported an average 6.0 ± 2.79 symptoms. Figure 1 illustrates the distribution of the number of symptoms reported by the total population.

Figure 1

Distribution of Number of Symptoms Reported



The number of symptoms reported at the time of injury was found to be a significant predictor of athletes suffering a prolonged recovery period. For each additional symptom reported, an athlete had a 26% greater chance of experiencing a prolonged recovery period (OR 1.26, 95% CI 1.21 – 1.32, $p < 0.001$).

Discussion

The purpose of this study was to examine whether the number of symptoms reported at the time of injury was predictive of an athlete experiencing a typical or prolonged recovery period from sport-related concussion. The findings of this study suggest that reporting a greater number of symptoms of sport-related concussion at the time of injury increase the likelihood of a prolonged recovery time. This finding not only makes practical sense, but it also echoes the findings of other studies (Kerr et al., 2018; Meehan et al., 2014; Schilling et al., 2020; Thomas et al., 2018; Zuckerman et al., 2016). As previously mentioned, many studies examine collegiate aged athletes or factors that contribute to a longer recovery time than the time frame examined during this study.

The findings of Meehan et al. (2014), Putukian et al. (2021), Schilling et al. (2020), and Thomas et al. (2018) are in agreement with the findings of this study. Thomas et al. (2018) utilized a population of children, ages 10 through 17, and found that as total symptom score increased so did recovery time. Meehan et al. (2014) also found that total symptom score at the time of injury was the only significant predictor of the 28-day recovery period. Putukian et al. (2021) found that total symptom score was strongly correlated with extended return to play times in collegiate athletes. Schilling et al. (2020) found that total symptom score was a predictor of an athlete having a recovery time of 28 days or greater. Total symptom score is the sum of symptom severity scores which is not exactly the same as the number of symptoms reported at the time of injury. However, these values are similar because in theory patients who report a greater number of symptoms would have a higher total symptom score.

More directly related to this study, Schilling et al. (2020), Kerr et al. (2018), and Zuckerman et al. (2016) all studied the relationship between the number of reported symptoms and recovery times of greater than 28 days. All three of these studies found that a greater number of total symptoms reported at the time of injury predicted a longer recovery period. This study defined a prolonged recovery period as 8 through 28 days which is shorter than the three aforementioned studies. Though there is a slight difference in the recovery periods between the studies, the findings of this study were in agreement with Schilling et al. (2020), Kerr et al. (2018), and Zuckerman et al. (2016) which all reported a greater number of symptoms reported at the time of injury is predictive of an increased recovery time.

Any healthcare practitioner who assesses an athlete for sport-related concussion should do a symptom assessment as a part of that evaluation. During the symptom assessment, something as simple as the number of symptoms that an athlete reports can be predictive of longer recovery period from sport-related concussion. Establishing the expectation of what could be a longer recovery time helps coaches, parents, and healthcare practitioners manage athlete expectations, returning to play, and returning to the classroom much safer. While each athlete should be evaluated by a trained healthcare professional and treated as an individual on a case-by-case basis, expecting a longer recovery period based on the number of symptoms reported could help mitigate some adverse effects of recovery such as reinjury, depression, and learning loss.

There were two primary limitations of the study. Firstly, the sample of participants in the study was a convenience sample. Secondly, the data used in this study was collected during from 2011 through 2014. Future research on this topic should include the examination of cutoff numbers of symptoms that would predict a typical recovery, prolonged recovery, and postconcussion syndrome.

To conclude, this study shows that athletes who present with a greater number of symptoms at the time of injury are more likely to require a longer recovery time. This finding is in agreement with other sport-related concussion research (Kerr et al., 2018;

Meehan et al., 2014; Putukian et al. (2021), Schilling et al., 2020; Thomas et al., 2018; Zuckerman et al., 2016). Healthcare practitioners should still examine and treat all sport-related concussions individually. However, the expectation of a lengthier recovery time at the time of injury due to the increased number of reported symptoms could help make safer and better return to play and return to learn decisions.

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CHAPTER III REFERENCES

Broglio, S. P., Cantu, R. C., Gioia, G. A., Guskiewicz, K. M., Kutcher, J., Palm, M., & Valovich McLeod, T. C. (2014). National athletic trainers' association position statement: management of sport concussion. *Journal of Athletic Training*, 49(2), 245-265. doi: 10.4085/1062-6050-49.1.07

Dompier, T. P., Marshall, S. W., Kerr, Z. Y., &Hayden, R. (2015). The national athletic treatment, injury and outcomes network (NATION): methods of surveillance program, 2011-2012 through 2013-2014. *Journal of Athletic Training*, 50(8), 862-869. doi: 10.4085/1062-6050-50.5.04

Kelly, J. P. (1999). Traumatic brain injury and concussion in sports. *Journal of the American Medical Association*, 282(10), 989-991. doi:10.1001/jama.282.10.989

Kerr, Z. Y., Zuckerman, S. L., Wasserman, E. B., Vander Vegt, C. B., Yengo-Kahn, A., Buckley, T. A., Solomon, G. S., Sills, A. K., & Dompier, T. P. (2018). Factors associated with post-concussion syndrome in high school student-athletes. *Journal of Science and Medicine in Sport*, 21(5), 447-452. doi: 10.1016/j.jsams.2017.08.025

Lau, B. C., Kontos, A. P., Collins, M. W., Mucha, A., & Lovell, M. R. (2011). Which on-field signs/symptoms predict protracted recovery from sport-related concussion among high school football players?. *The American Journal of Sports Medicine*, 39(11), 2311-2318. doi: 10.1177/0363546511410655

McCrea, M. et al. (2003). Acute effects and recovery time following concussion in collegiate football players the NCAA concussion study. *Journal of the American Medical Association*, 290(19), 2556-2563.

McCrea, M., Guskiewicz, K. Randolph, C., Barr, W. B., Hammeke, T. A., Marshall, S. W., Powell, M. R., Ahn, K. W., Wang, Y., & Kelly, J. P. (2012). Incidence, clinical course, and predictors of prolonged recovery time following sports-related concussion in high school and collegiate athletes. *Journal of International Neuropsychological Society*, 18, 1-12. doi: 10.1017/S1355617712000872

McCrea, M., Randolph, C., Barr, W. B., & Hammeke, T. A. (2012). Incidence, clinical course, and predictors of prolonged recovery time following sport-related concussion in high school and college athletes. *Journal of the International Neuropsychological Society*, 18, 1-12. doi: 10.1017/S1355617712000872

McCrory, P., Meeuwisse, W., Dvorak, J., Aubry, M., Bailes, J., Broglio, S., Cantu, R. C., Cassidy, D., Ellenbogen, R., Emery, C., Engebretsen, L., Fedderman-Demont, N., Giza, G. C., Guskiewicz, K. M., Herring, S., Iverson, G. L., Johnston, K. M., Kissick, J., . . . Vos, P. E. (2017). Consensus statement on concussion in sport – the 5th international conference on concussion in sport held in berlin, October 2016. (2017). *British Journal of Sports Medicine*, 51(11), 838-847.

Meehan, W. P., Mannix, R., Monuteaux, M. C., Stein, C. J., & Bachur, R. G. (2014). Early symptom burden predicts recovery after sport-related concussion. *Neurology*, 83, 2204-2210.

Notebaert, A. J. & Guckiewicz, K. M. (2005). Current trends in athletic training practice for concussion assessment and management. *Journal of Athletic Training*, 40(4), 320-325.

Putukian, M., Riegler, K., Smalfe, S., Bruce, J., &Echemendia, R. (2021) Preinjury and postinjury factors that predict sports-related concussion and clinical recovery time. *Clinical Journal of Sports Medicine*, 31(1), 15-22. doi: http://dx.doi.ord/10.1097/JSM.0000000000000705

Schilling, S., Mansour, A., Sullivan, L., Ding, K., Pommering, T., & Yang, J. (2020) Symptom burdens and profiles in concussed children with and without prolonged recovery. *International Journal of Environmental Research and Public Health*, 17, 351-361. doi: 10.3390/ijerph17010351

Thomas, D. J., Coxe, K., Hongmei, L., Pommering, T. L., Young, J. A., Smith, G. A., & Yang, J. (2018) Length of recovery from sports-related concussions in pediatrics patients treated at concussion clinics. *Clinical Journal of Sports Medicine*, 28(1), 56-63. doi: http://dx.doi.org/10.1097/JSM.0000000000000413.

Zuckerman, S. L., Yengo-Kahn, A. M., Buckley, T. A., Solomon, G. S., Sills, A. K., & Kerr, Z. Y. (2016). Predictors of postconcussion syndrome in collegiate student-athletes. *Neurosurgical Focus*, 40(4), 1-10. doi: 10.3171/2016.1.FOCUS15593

CHAPTER IV

REPORTED SYMPTOMS AND OTHER FACTORS PRESENT AT THE TIME OF INJURY AND THE EFFECT ON RECOVERY TIME FROM SPORT-RELATED CONCUSSION IN HIGH-SCHOOL ATHLETES

Sport-related concussion is an international public health and athletics issue (Kelly, 1999; McCrory et al., 2017). The most recent definition of sport-related concussion, according to the Concussion in Sport Group, was "representing the immediate and transient symptoms of a traumatic brain injury (TBI)" (McCrory et al., 2017, p. 839). The group also notes that sport-related concussions are caused by a direct blow to the head or a force to the body that is transmitted to the head (McCrory et al., 2017). Considering the variety of ways that a blow to head can occur, both directly and indirectly, athletes competing in youth sports ranging all the way to up athletes competing in professional sports are at risk of experiencing a sport related concussion at some point during sport activity or at an activity outside of sport.

When healthcare practitioners assess a sport-related concussion, the most widely utilized tool is a symptom checklist or symptom assessment (Broglio et al., 2014; McCrea et al., 2003; McCrory et al., 2017; Notebaert & Guskiewicz, 2005). Though sport-related concussion assessments often utilize symptoms reported by the athlete, research that has been performed surrounding symptomology of sport-related concussion and prognosis for recovery can be somewhat limited and often focuses on predicting postconcussion syndrome or a recovery time of greater than 28 days (Kerr et al., 2018; Lau et al., 2011; Schilling et al., 2020; Zuckerman et al., 2016).

Within the literature, there were a variety of symptoms reported as potential predictors of a longer than normal sport-related concussion recovery. Amnesia, both retrograde amnesia and anterograde amnesia, was tagged as predictors of prolonged recovery and postconcussion syndrome in both college aged adults and high school aged populations (Kerr et al., 2018; McCrea et al., 2012; Schilling et al., 2020; Zuckerman et al., 2016). Collins et al. (2003) mentioned retrograde and anterograde amnesia as predictors of poor clinical presentation. Putukian et al. (2021) reported headache as increasing the liklihood prolonged recovery in collegiate aged athletes. Putukian et al. (2021), Kerr et al. (2018), and Lau et al. (2011) all found balance issues to be indicative of a longer than normal recovery time in both high school and collegiate athletes. Difficulty concentrating has also been linked with prolonged recovery from sport-related concussion (Kerr, et al., 2018; Putukian et al., 2021; Zuckerman et al., 2016). Other symptoms loosely linked to prolonged recovery or postconcussion syndrome are sensitivity to noise, sensitivity to light, and insomnia (Kerr et al., 2018; Zuckerman et al., 2016).

In addition to symptoms, there were other factors reported as potential predictors of prolonged recovery. Sex can be predictor of a prolonged recovery period (Schilling et al., 2020; Thomas et al., 2018). Females under the age of 18 were found to have a prolonged recovery period (Schilling et al., 2020; Thomas et al., 2018). Zuckerman et al. (2016) and Schilling et al. (2020) found recurrent sport-related concussion injury to be a predictor of a 28 day or more recovery time in college aged adults and children under age 18, respectively.

While the findings of these aforementioned studies are valuable, many examine predictors of a recovery time of more than 28 days (Kerr et al., 2018; Meehan et al., 2014; Schilling et al., 2020; Zuckerman et al., 2016). While there may be parallels between the factors and symptoms that result in a 28 day or longer recovery period and the factors or symptoms that predict a prolonged period, it is important to differentiate between a typical recovery and a prolonged recovery that is not more than 28 days in length. The purpose of the second study was to examine any symptoms or factors present at the time of injury that would predict a prolonged recovery from sport-related concussion. It was hypothesized that some combination of sex, recurrent injury, anterograde amnesia, retrograde amnesia, balance issues, insomnia, light sensitivity, noise sensitivity, and difficulty concentrating would be predictive of a prolonged recovery period.

Methods

The NATION is a program designed to collect a wide variety of data related to athletic injuries in high-school athletes (Dompier et al., 2015). Certified athletic trainers evaluated and reported injuries occurring both at practices and at games (Dompier et al., 2015). In all, injuries from 27 sports across 147 high schools spanning 26 different states from the 2011-2012 until the 2013-2014 school years were included in the dataset (Dompier et al., 2015). Of the high schools included in the dataset, 84.4% were public, 98.6% were coeducational, 75.5% were in non-urban areas, and 51.0% had enrollments of less than 1,000 students (Kerr et al., 2018).

Data were recorded from electronic medical record programs used daily by athletic trainers (Dompier et al., 2015). The data essentially were collected from these programs and sent to Datalys Center to be checked for accuracy and completeness via both manual and automated checks (Dompier et al., 2015). The items pertinent to this study are the grade level of the athlete, sex, sport, type of participation (practice or game), mechanism of injury, time lost from participation, and whether or not the injury was new or recurrent. In regard to sports related concussion, there were a variety of data points collected. The athletic trainers completed a detailed injury report containing dichotomous yes/no items for 17 different symptoms associated with concussion, a dichotomous yes/no item indicating whether or not the injury is a concussion, and a categorical variable related to when all concussion symptoms resolved.

Data Analysis

Data was analyzed to describe the athletes in the typical and prolonged recovery groups. Categorical data was presented as percentages of the total population included in the analysis. Logistic regression estimated odds ratios and 95% confidence intervals of the factors contributing to a prolonged or typical recovery were reported. Using any variables with a p value of < 0.10 from the univariate analyses, a multivariate model was created. A stepwise logistic regression procedure was used to determine the most parsimonious model with the significant variables from the univariate analysis as the independent variables. The dependent variable was the dichotomized variable of whether an athlete experienced a typical or prolonged recovery. Athletes whose symptoms resolved at or before seven days were in the typical recovery group (McCrea et al., 2012). Athletes whose symptoms resolved in longer than 28 days were excluded from the study and considered to have postconcussion syndrome (Kerr et al., 2018; Zuckerman et al., 2016) The remaining were athletes whose symptoms resolved at greater than seven days but not more than 28 days. These were placed into the prolonged recovery group. Data were analyzed using Statistical Package for Social Sciences (SPSS) (version 28.0).

Results

Only sport-related concussions containing all data points were included in the study, a total of 1,313. Descriptive statistics of sex, grade level, recurrent injury, competition, helmet status, symptoms, and recovery time are listed in Table 2. The frequency and percentage for each category within the variables was reported. Additionally, the frequency and percentage for whether each person had a typical or prolonged recovery period was reported within each variable as well.

Males comprised 967 of the 1,313 (73.6%) sport-related concussions in the population. Freshman was the largest class year represented in the study with 496 cases (37.8%). There were 1,282 (97.6%) new injuries in the population. Injuries occurring during competition accounted for 622 (47.4%) injuries. Sports in which helmets are utilized by the majority of the team during part of the game accounted for 838 (63.8%) of the injuries. The most commonly reported symptom was headache, 1269 (96.6%). The least commonly reported symptom was loss of consciousness, 18 (1.4%). Overall, 703 (53.5%) athletes experienced a typical recovery time while 610 (46.5%) athletes experienced a prolonged recovery time.

Table 2

Descriptive Statistics of Study Variables and Recovery Period

Characteristic	Total	Typical Recovery	Prolonged Recovery
Sex (no. [%])			
Male	967 (73.6)	540 (41.2)	427 (32.5)
Female	346 (26.4)	163 (12.4)	183 (13.9)
Grade Level (no. [%])			
Freshman	496 (37.8)	273 (20.8)	223 (17.0)
Sophomore	336 (25.6)	168 (12.8)	168 (12.8)
Junior	257 (19.5)	127 (9.7)	130 (9.8)
Senior	224 (17.1)	135 (10.3)	89 (6.8)
Injury Status (no. [%])			
New Injury	1282 (97.6)	664 (52.1)	598 (45.5)
Recurrent Injury	31 (2.4)	19 (1.4)	12 (0.9)
Competition Status (no. [%])			
During a Competition	622 (47.4)	318 (24.2)	304 (23.2)
Not During a Competition	691 (52.6)	385 (29.3)	306 (23.3)
Helmet Status (no. [%])[a]			
Helmet	838 (63.8)	459 (35.0)	379 (28.9)
No Helmet	475 (36.2)	244 (18.6)	231 (17.6)
Symptom (no. [%])			
Drowsiness			
Yes	458 (34.9)	206 (15.7)	252 (19.1)
No	855 (65.1)	497 (37.9)	358 (27.3)

Characteristic	Total	Typical Recovery	Prolonged Recovery
Insomnia			
Yes	310 (23.6)	119 (9.1)	191 (14.5)
No	1003 (76.4)	584 (44.5)	419 (31.9)
Noise Sensitivity			
Yes	512 (39.0)	190 (14.5)	322 (24.5)
No	801 (61.0)	513 (39.1)	288 (21.9)
Light Sensitivity			
Yes	618 (47.1)	254 (19.3)	364 (27.7)
No	695 (52.9)	449 (34.2)	246 (18.7)
Visual Impairment			
Yes	236 (18.0)	95 (7.2)	141 (10.7)
No	1077 (82.0)	608 (46.3)	469 (35.7)
Balance Issues			
Yes	379 (28.9)	151 (11.5)	228 (17.4)
No	934 (71.1)	552 (42.0)	382 (29.1)
Tinnitus			
Yes	96 (7.3)	38 (2.9)	58 (4.4)
No	1217 (92.7)	665 (50.6)	552 (42.1)
Nausea			
Yes	364 (27.7)	156 (11.9)	208 (15.8)
No	949 (72.3)	547 (41.7)	402 (30.6)

Characteristic	Total	Typical Recovery	Prolonged Recovery
Loss of Consciousness			
Yes	18 (1.4)	10 (0.8)	8 (0.6)
No	1295 (98.6)	693 (52.8)	602 (45.8)
Irritability			
Yes	223 (17.0)	89 (6.7)	134 (10.2)
No	1090 (83.0)	614 (46.8)	476 (36.3)
Hyperexcitability			
Yes	47 (3.6)	30 (2.3)	17 (1.3)
No	1266 (96.4)	673 (51.3)	593 (45.2)
Headache			
Yes	1269 (96.6)	668 (50.9)	601 (45.8)
No	44 (3.4)	35 (2.7)	9 (0.7)
Dizziness			
Yes	985 (75.0)	490 (37.3)	495 (37.7)
No	328 (25.0)	213 (15.2)	115 (8.8)
Feeling Disoriented			
Yes	263 (20.0)	123 (9.4)	140 (10.7)
No	1050 (80.0)	580 (44.2)	470 (35.8)
Difficulty Concentrating			
Yes	797 (60.7)	355 (27.9)	442 (33.7)
No	516 (39.3)	348 (26.5)	168 (12.8)

Characteristic	Total	Typical Recovery	Prolonged Recovery
Retrograde Amnesia			
Yes	48 (3.7)	23 (1.8)	25 (1.9)
No	1265 (96.3)	680 (51.8)	585 (44.6)
Posttraumatic Amnesia			
Yes	100 (7.6)	53 (4.0)	47 (3.6)
No	1213 (92.4	650 (49.5)	563 (42.9)

[a] Helmeted category was divided up by sport. Helmeted sports were defined as sports where the majority of the active players wear a helmet part or all of the time.

The results of the univariate analysis are shown in Table 3. Odds ratio, 95% confidence intervals, and *p*-value for each univariate analysis are listed in Table 3. From the univariate analyses, sport-related concussion symptoms associated with an increased odds of a prolonged recovery period were balance issues (OR 2.18, CI 1.71 – 2.78, p <0.001), difficulty concentrating (OR 2.58, CI 2.05 – 3.25, p <0.001), dizziness (OR 1.87, CI 1.44 – 2.42, p <0.001), drowsiness (OR 1.70, CI 1.35 – 2.13, p <0.001), feeling disoriented (OR 1.41, CI 1.07 – 1.84, p = 0.01), headache (OR 3.50, CI 1.67 – 7.34, p <0.001), insomnia (OR 2.24, CI 1.72 – 2.90, p <0.001), irritability (OR 1.94, CI 1.45 – 2.61, p <0.001), nausea (OR 1.81, CI 1.42 – 2.32, p <0.001), sensitivity to light (OR 2.62, CI 2.09 – 3.27, p <0.001), sensitivity to noise (OR 3.01, CI 2.40 – 3.80, p <0.001), tinnitus (OR 1.84, CI 1.20 – 2.81, p <0.001), and vision impairment (OR 1.92, CI 1.45 – 2.56, p <0.001). Other factors that were associated with an increased odds of prolonged recovery during the univariate analysis were grade level (p = 0.05), sex (OR 0.70, CI 0.55

– 0.91, *p* = 0.01), and competition status (OR 1.20, CI 0.97 – 1.50, *p* = 0.10). These aforementioned variables were all used in the multivariate analysis.

Table 3

Results of Univariate Analysis of Typical vs. Prolonged Recovery

Variable	OR (95% CI)	p-value
Symptoms[a]		
Balance Issues	2.18 (1.71 - 2.78)	<0.001
Difficulty Concentrating	2.58 (2.05 - 3.25)	<0.001
Dizziness	1.87 (1.44 - 2.42)	<0.001
Drowsiness	1.70 (1.35 - 2.13)	<0.001
Feeling Disoriented	1.41 (1.07 - 1.84)	0.01
Headache	3.50 (1.67 - 7.34)	<0.001
Hyperexcitable	0.64 (0.35 - 1.18)	0.15
Insomnia	2.24 (1.72 - 2.90)	<0.001
Irritable	1.94 (1.45 - 2.61)	<0.001
Loss of Consciousness	0.92 (0.36 - 2.35)	0.86
Nausea	1.81 (1.42 - 2.32)	<0.001
Posttraumatic Amnesia	1.02 (0.68 - 1.54)	0.91
Retrograde Amnesia	1.26 (0.71 -2.25)	0.43
Sensitivity to Light	2.62 (2.09 - 3.27)	<0.001
Sensitivity to Noise	3.01 (2.40 - 3.80)	<0.001
Tinnitus	1.84 (1.20 - 2.81)	<0.001
Visual Impairment	1.92 (1.45 - 2.56)	<0.001

Variable	OR (95% CI)	p-value
Grade[b]		0.05
Freshman	0.87 (0.62 - 1.08)	0.15
Sophomore	1.0	
Junior	1.02 (0.74 - 1.42)	0.88
Senior	0.66 (0.47 - 0.93)	0.02
Helmet Status[c]	0.87 (0.70 - 1.09)	0.24
Sex[d]	0.70 (0.55 - 0.91)	0.01
Competition Status[e]	1.20 (0.97 - 1.50)	0.10
Recurrent Injury[f]	0.72 (0.35 - 1.50)	0.72

[a]No symptom present = 0, Yes symptom present = 1.

[b]'Sophomore' class was used as a reference.

[c]No helmet = 0, Helmet = 1.

[d]Female = 0, Male = 1.

[e]Not in a competition = 0, In a competition = 1.

[f]Not a recurrent injury = 0, Recurrent injury = 1.

The results of the final multivariate analysis are shown in Table 3. Sex, specifically being a female, was associated with an increased odds for a prolonged recovery period (OR 0.75, CI 0.57 – 0.97, $p = 0.028$). Concussion symptoms associated with odds for a prolonged recovery period were balance issues (OR 1.48, CI 1.14 – 1.93, p = 0.003), difficulty concentrating (OR 1.74, CI 1.35 – 2.24, p < 0.001), headache (OR 2.20, CI 1.03 – 4.71, $p = 0.042$), insomnia (OR 1.42, CI 1.07 – 1.89, $p = 0.015$), sensitivity to light (OR 1.35, CI 1.02 – 1.80, $p = 0.039$), and sensitivity to noise (OR 1.81, CI 1.35 – 2.42, $p < 0.001$).

Table 4

Multivariate Logistic Regression Model Predicting Prolonged Concussion

Variable	*B*	*SE*	OR (95% CI)	p-value
Balance Issues [a]	0.40	0.14	1.48 (1.14 - 1.93)	0.003
Difficulty Concentrating [a]	0.55	0.13	1.74 (1.35 - 2.24)	<0.001
Headache [a]	0.80	0.39	2.20 (1.03 - 4.71)	0.042
Insomnia [a]	0.35	0.15	1.42 (1.07 - 1.89)	0.015
Sensitivity to Light [a]	0.30	0.15	1.35 (1.02 - 1.80)	0.039
Sensitivity to Noise [a]	0.59	0.15	1.81 (1.35 - 2.42)	<0.001
Sex [b]	-0.29	0.13	0.75 (0.57 - 0.97)	0.028

[a] No symptom present = 0, Yes symptom present = 1

[b] Female = 0, Male = 1.

Discussion

The purpose of the second study was to examine any symptoms or factors present at the time of injury that would predict a prolonged recovery from sport-related concussion. It was hypothesized that some combination of sex, recurrent injury, anterograde amnesia, retrograde amnesia, balance issues, insomnia, light sensitivity, noise sensitivity, and difficulty concentrating would be predictive of a prolonged recovery period. As hypothesized, sex, balance issues, difficulty concentrating, headache, insomnia, sensitivity to light, and sensitivity to noise were all significant predictors of a prolonged recovery period. However, recurrent injury, retrograde amnesia, and anteriograde amnesia were not significant predictors of a prolonged recovery period.

Balance issues, noise sensitivity, light sensitivity, insomnia, headache, and difficulty concentrating were discovered to be significant predictors of a prolonged recovery period. Putukian et al. (2021) reported headache as a predictor of prolonged recovery in college athletes. Putukian et al. (2021), Kerr et al. (2018), and Lau et al. (2011) all found dizziness and loss of balance as indicators of longer than normal recovery in both high school and collegiate athletes. Putukian et al. (2021), Kerr et al. (2018), and Zuckerman et al. (2016) all found concentration difficulties as a predictor of PCS or prolonged recovery in high school and collegiate athletes. Kerr et al. (2018) reported insomnia and noise sensitivity as predictors of postconcussion syndrome in high school athletes. Zuckerman et al. (2016) reported light sensitivity and insomnia as predictors of postconcussion syndrome in collegiate athletes.

The findings of Putkian et al. (2021) in regard to headache, dizziness, and concentration being significant predictors of a longer than normal recovery period are in agreement with this study. The findings of Zuckerman et al. (2016) in regard to light sensitivity, insomnia, and concentration being significant predictors of a longer than normal recovery period are in agreement with this study. The findings of Kerr et al. (2018) in regard to dizziness, insomnia, and noise sensitivity being significant predictors of a longer than normal recovery period are in agreement with this study. The findings of

Lau et al. (2011) in regard to dizziness being significant predictors of a longer than normal recovery period are in agreement with this study.

In addition to symptoms, sex was a factor that was found to be a significant predictor of prolonged recovery. The findings of this study suggest that females are more likely to experience a prolonged recovery period than males. The findings that females are more apt to experience a prolonged recovery period is supported by other studies. Thomas et al. (2018) and Schilling et al. (2020) both found that females are at an increased risk to experience an extended recovery period following sport-related concussion.

Although recurrent injury, a history of sport-related concussion, posttraumatic amnesia, retrograde amnesia and anteriograde amnesia have been found throughout the literature as predictors of longer recovery time from sport-related concussion, these were not found to be significant predictors in this study. Zuckerman et al. (2016) and Schilling et al. (2020) both found recurrent sport-related concussion or sport-related concussion injury history to be linked with longer recovery times. Retrograde amnesia was mentioned multiple times in the literature as potential predictors of a prolonged recovery period or postconcussion syndrome (Kerr et al., 2018; McCrea et al., 2012; Schilling et al., 2020; Zuckerman et al., 2016). Kerr et al. (2018), McCrea et al. (2012), and Schilling et al. (2020) all found anterograde amnesia or posttraumatic amnesia to be significant predictors of prolonged recovery periods or postconcussion syndrome. Some of these aforementioned studies examined postconcussion syndrome or recovery of longer than 28 days while some examined an increase in recovery time.

While the study did not support a history of sport-related concussion, posttraumatic amnesia, retrograde amnesia and anteriograde amnesia being significant predictors of a prolonged recovery, the differences between this study results on the previous ones may be linked to methodology or the study population. Kerr et al. (2018), Schilling et al. (2020), and Zuckerman et al. (2016) all examined differences between a typical recovery time and a recovery time of more than 28 days, whereas this study examined differences between a typical recovery time and a prolonged recovery time of eight through 28 days. Collins et al. (2003) did not seek to differentiate between recovery periods but investigated the causes of poor presentation at the time of injury. Zuckerman et al. (2016) and McCrea et al. (2012) utilized samples that included college aged athletes. Additionally, the McCrea et al. (2012) study did not exclude individuals from the study if they had symptoms lasting longer than 28 days. As previously stated, these differences in methodology could explain the this study not supporting the aforementioned results.

There were a few different limitations of this study. Firstly, the study participants used were a convenience sample. Secondly, data was collected years ago during the 2011-2014 seasons. Lastly, some factors of concussion were not represented in the study. Examples of these factors that could be excluded were total symptom burden, learning disabilities, mental health concerns, family history, or psychiatric illnesses.

Future research on this topic should focus on categorizing symptoms and evaluating how symptoms in each category may affect protracted recovery times. Additionally, future research should attempt to differentiate between the various recovery windows with a multinomial approach. Other topics to be examined by future research should include examining the effect of year-round play and training status on recovery time and incidence. Lastly, research should examine the use of various therapies and how they may affect symptomology and recovery.

In conclusion, this study shows that females are more likely to experience a prolonged recovery than males. Additionally, athletes who present with difficulty concentrating, headache, balance issues, sensitivity to light, sensitivity to noise, or insomnia may be more apt to experience longer than normal recovery times from sport-related concussion. The findings of this study are echoed throughout available studies. All healthcare practitioners should still evaluate and make decisions about sport-related concussions on a case-by-case basis. Practically speaking, healthcare practitioners who expect a longer recovery time based on the symptomology or other factors at the time of injury could help make more accurate, safer return to play decisions as well as better decisions related to returning to the classroom for any student-athletes. This expectation of a prolonged recovery at the time of injury increases safety and can improve outcomes for patients who experience a sport-related concussion.

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CHAPTER IV REFERENCES

Broglio, S. P., Cantu, R. C., Gioia, G. A., Guskiewicz, K. M., Kutcher, J., Palm, M., & Valovich McLeod, T. C. (2014). National athletic trainers' association position statement: management of sport concussion. *Journal of Athletic Training*, 49(2), 245-265. doi: 10.4085/1062-6050-49.1.07

Collins, M. W., Iverson, G. L., Lovell, M. R., McKeag, D. B., Norwig, J., & Maroon, J. (2003). On-field predictors of neuropsychological and symptom deficit following sports-related concussion. *Clinical Journal of Sports Medicine*, 13, 222-229.

Kelly, J. P. (1999). Traumatic brain injury and concussion in sports. *Journal of the American Medical Association*, 282(10), 989-991. doi:10.1001/jama.282.10.989

Kerr, Z. Y., Zuckerman, S. L., Wasserman, E. B., Vander Vegt, C. B., Yengo-Kahn, A., Buckley, T. A., Solomon, G. S., Sills, A. K., & Dompier, T. P. (2018). Factors associated with post-concussion syndrome in high school student-athletes. *Journal of Science and Medicine in Sport*, 21(5), 447-452. doi: 10.1016/j.jsams.2017.08.025

Lau, B. C., Kontos, A. P., Collins, M. W., Mucha, A., & Lovell, M. R. (2011). Which on-field signs/symptoms predict protracted recovery from sport-related concussion among high school football players?. *The American Journal of Sports Medicine*, 39(11), 2311-2318. doi: 10.1177/0363546511410655

McCrea, M. et al. (2003). Acute effects and recovery time following concussion in collegiate football players the NCAA concussion study. *Journal of the American Medical Association*, 290(19), 2556-2563.

McCrea, M., Randolph, C., Barr, W. B., & Hammeke, T. A. (2012). Incidence, clinical course, and predictors of prolonged recovery time following sport-related concussion in high school and college athletes. *Journal of the International Neuropsychological Society*, 18, 1-12. doi: 10.1017/S1355617712000872

McCrory, P., Meeuwisse, W., Dvorak, J., Aubry, M., Bailes, J., Broglio, S., Cantu, R. C., Cassidy, D., Ellenbogen, R., Emery, C., Engebretsen, L., Fedderman-Demont, N., Giza, G. C., Guskiewicz, K. M., Herring, S., Iverson, G. L., Johnston, K. M., Kissick, J., . . . Vos, P. E. (2017). Consensus statement on concussion in sport – the 5th international conference on concussion in sport held in berlin, October 2016. (2017). *British Journal of Sports Medicine*, 51(11), 838-847.

Notebaert, A. J. & Guckiewicz, K. M. (2005). Current trends in athletic training practice for concussion assessment and management. *Journal of Athletic Training*, 40(4), 320-325.

Putukian, M., Riegler, K., Smalfe, S., Bruce, J., &Echemendia, R. (2021) Preinjury and postinjury factors that predict sports-related concussion and clinical recovery time. *Clinical Journal of Sports Medicine*, 31(1), 15-22. doi: http://dx.doi.ord/10.1097/JSM.0000000000000705

Schilling, S., Mansour, A., Sullivan, L., Ding, K., Pommering, T., & Yang, J. (2020) Symptom burdens and profiles in concussed children with and without prolonged recovery. *International Journal of Environmental Research and Public Health*, 17, 351-361. doi: 10.3390/ijerph17010351

Thomas, D. J., Coxe, K., Hongmei, L., Pommering, T. L., Young, J. A., Smith, G. A., & Yang, J. (2018) Length of recovery from sports-related concussions in pediatrics patients treated at concussion clinics. *Clinical Journal of Sports Medicine*, 28(1), 56-63. doi: http://dx.doi.org/10.1097/JSM.0000000000000413.

Zuckerman, S. L., Yengo-Kahn, A. M., Buckley, T. A., Solomon, G. S., Sills, A. K., & Kerr, Z. Y. (2016). Predictors of postconcussion syndrome in collegiate student-athletes. *Neurosurgical Focus*, 40(4), 1-10. doi: 10.3171/2016.1.FOCUS15593

CHAPTER V:
OVERALL CONCLUSIONS

Sport related concussion has been a public health issue plaguing youth and adults all over the world (Kelly, 1999; McCrory et al., 2017). The most current definition of sport-related concussion is immediate and transient symptoms caused by a direct or indirect force to the head (McCrory et al., 2017). As a result of the various mechanisms of injury of sport-related concussion, athletes and non-athletes of all ages and levels of competition are at risk of injury. Symptoms of concussion can range from manageable to debilitating and include a variety of symptoms such as headache and dizziness (Lau et al., 2011). These symptoms may last anywhere from hours up to 28 days (McCrea et al., 2003).

Symptomology of sport-related concussion is important to healthcare practitioners, because in the evaluation of sport-related concussion, symptomology is the most widely used assessment tool (Broglio et al., 2014; McCrea et al., 2003; McCrory et al., 2017; Notebaert & Guskiewicz, 2005). Though sport-related concussion evaluation centers around subjective patient reporting, research related to symptomology and prognosis for recovery is somewhat limited (Lau et al., 2011). Thus, the two aims of this dissertation were to examine the relationship between symptomology and prognosis for recovery.

The purpose of the first study was to examine whether the number of sport-related concussion symptoms reported at the time of injury was predictive of whether an athlete would experience a typical or prolonged recovery period from sport-related concussion. Based on available research, it was hypothesized that an increase in the number of symptoms reported at the time of injury would result in an increased risk of experiencing a prolonged recovery time. As hypothesized, a greater number of symptoms reported at the time of injury did in fact indicate an increased risk of an athlete experiencing a prolonged recovery time.

The purpose of the second study was to examine any symptoms or factors present at the time of injury that would predict a prolonged recovery period from sport-related concussion. Based on the literature, it was hypothesized that some combination of sex, recurrent injury, anterograde amnesia, retrograde amnesia, balance issues, insomnia, light sensitivity, noise sensitivity, and difficulty concentrating would be predictive of a prolonged recovery period. Part of this hypothesis was not supported; retrograde amnesia, anterograde amnesia, and recurrent injury were not found to be significant predictors of a prolonged recovery period even though there was evidence in the literature that indicated those could be significant predictors. On the other hand, sex, balance issues, difficulty concentrating, headache, insomnia, sensitivity to light, and sensitivity to noise were all found to be significant predictors of a prolonged recovery period of sport-related concussion. These predictors were supported by other research as well as this study.

The findings from both studies reveal important information about the potential prognosis of recovery from sport-related concussion in high school athletes. All items found to be significant predictors of a prolonged recovery period can be easily assessed during a sport-related concussion evaluation, whether that be an athletic trainer on the sideline or a primary care physician in a medical office. Separately, the findings of each study are important and useful to all healthcare practitioners who deal with sport-related concussions. Together, these two studies provide even more insight into the potential for athletes to experience a prolonged recovery period.

Future research into symptomology of sport-related concussion should take on a multinomial approach, attempting to differentiate between more than just two different recovery patterns. Even though the findings from this study may indicate that an athlete may require an extended recovery period, it is important to note that all healthcare practitioners should still evaluate sport-related concussions on a case-by-case basis. The expectation of a longer recovery time at the time of injury will help make better, safer decisions regarding returning to play and returning to the classroom following sport-related concussion injury.

DISSERTATION REFERENCES

American Academy of Neurology. (1997). Practice parameter: the management of concussion in sports (summary statement). *Neurology*, 48, 581-585.

Aubry, M., Cantu, R., Dvorak, J., Graf-Baumann, T., Johnston, K., Kelly, J., Lovell, M., McCrory, P., Meeuwisse, W., & Schamasch, P. (2002). Summary and agreement statement of the first international conference on concussion in sport, Vienna 2001. *British Journal of Sports Medicine*, 36, 6-10.

Bauer, R., & Fritz, H. (2004). Pathophysiology of traumatic injury in the developing brain: an introduction and short update. *Experimental and Toxicology Pathology*, 56, 65-73.

Bey, T., & Ostick, B. (2009). Second impact syndrome. *The Western Journal of Emergency Medicine*, 10(1), 6-10.

Broglio, S. P., & Puetz, T. W. (2008). The effect of sport concussion on neurocognitive function, self-report symptoms and postural control a meta-analysis. *Sports Medicine*, 38(1), 53-57. doi: 0112-1642/08/0001-0053/$48.00/0

Broglio, S. P., Cantu, R. C., Gioia, G. A., Guskiewicz, K. M., Kutcher, J., Palm, M., & Valovich McLeod, T. C. (2014). National athletic trainers' association position statement: management of sport concussion. *Journal of Athletic Training*, 49(2), 245-265. doi: 10.4085/1062-6050-49.1.07

Cantu, R. C. (1992). Cerebral concussion in sport management and prevention. *Sports Medicine*, 14(1), 64-74.

Castile, L., Collins, C. L., McIlvain, N. M., & Comstock, R. D. (2012). The epidemiology of new vs recurrent concussion in high school athletes, 2005-2010.

British Journal of Sports Medicine, 2012, 46, 603-610. doi: 10.1136/bjsports-2011-090115

Chrisman, S. P. D., Lowry, S., Herring, S. A., Kroshus, E., Hoopes, T. R., Higgins, S. K., & Rivara, F. P. (2019). Concussion incidence, duration, and return to school and sport in 5- to 14-year-olds american football athletes. *The Journal of Pediatrics*, 207, 176-184.

Chun, B. J., Furutani, T., Oshiro, R., Young, C., Prentiss, G., & Murata, N. (2021). Concussion epidemiology in youth sports: sports study of statewide high school sports program. *Sports Health*, 13(1), 18-24. doi: 10.1177/1941738120932570

Collins, M. W., Iverson, G. L., Lovell, M. R., McKeag, D. B., Norwig, J., & Maroon, J. (2003). On-field predictors of neuropsychological and symptom deficit following sports-related concussion. *Clinical Journal of Sports Medicine*, 13, 222-229.

Committee to Study Head Injury Nomenclature (1966). Report. *Clinical Neurosurgery*, 12, 386-387.

Denny-Brown, D. E. & Russell, W. R. (1941). Experimental cerebral concussion. *Brain*, 64, 93-164.

Dompier, T. P., Marshall, S. W., Kerr, Z. Y., &Hayden, R. (2015). The national athletic treatment, injury and outcomes network (NATION): methods of surveillance program, 2011-2012 through 2013-2014. *Journal of Athletic Training*, 50(8), 862-869. doi: 10.4085/1062-6050-50.5.04

Field, M., Collins, M. W., Lovell, M. R., & Maroon, J. (2003). Does age play a role in recovery from sports-related concussion? a comparison of high school and collegiate athletes. *Journal of Pediatrics*, 142(5), 546-553. doi: 10.1067/mpd.2003.190

Gerberich, S. G., Priest, J. D., Boen, J. R., Straub, C. P., & Maxwell, R. E. (1983). Concussion incidences and severity in secondary school varsity football players. *The American Journal of Public Health*, 73(12), 1370-1375.

Gessel, L. M., Fields, S. K., Collins, C. L., Dick, R. W., & Comstock, R. D. (2007). Concussions among united states high school and collegiate athletes. *Journal of Athletic Training*, 42(4), 495-503.

Giza, C. C. & Hovda, D. A. (2001). The neurometabolic cascade of concussion. *Journal of Athletic Training*, 36(3), 228-235.

Giza, G. C. & Hovda, D. A. (2014). The new neurometabolic cascade of concussion. *Neurosurgery*, 75(4), S24-S33. doi: 10.1227/NEU.0000000000000505

Goldsmith, W. & Plunkett, J. (2004). A biomechanical analysis of the causes of traumatic brain injury in infants and children. *American Journal of Forensic Medicine and Pathology,* 25, 89-100.

Gurdjian, E. S., Webster, J. E., & Arnkoff, H. (1943). Acute craniocerebral trauma: Surgical and pathologic considerations based upon 151 consecutive autopsies. *Surgery*, *13*(3), 333-353.

Guskiewicz, K. M., Weaver, N. L., Padua, D. A., & Garrett, W. E. (2000). Epidemiology of concussion in collegiate and high school football players. *The American Journal of Sports Medicine*, 28(5), 643-650. doi: 0363-5465/100/2828-0643$02.00/0

Halstead, M. E., McAvoy, K. Devore, C. D., Carl, R. Lee, R., & Logan, K. (2013). Returning to learning following concussion. *American Academy of Pediatrics*, 132(5), 948-957. doi: 10.1542/peds.2013-2867

Jefferson, G. (1944). The nature of concussion. *British Medical Journal*, 1, 1-5.

Kelly, J. P. (1999). Traumatic brain injury and concussion in sports. Journal of the American Medical Association, 282(10), 989-991. doi:10.1001/jama.282.10.989

Kerr, Z. Y., Zuckerman, S. L., Wasserman, E. B., Vander Vegt, C. B., Yengo-Kahn, A., Buckley, T. A., Solomon, G. S., Sills, A. K., & Dompier, T. P. (2018). Factors associated with post-concussion syndrome in high school student-athletes. *Journal of Science and Medicine in Sport*, 21(5), 447-452. doi: 10.1016/j.jsams.2017.08.025

Kucera, K. L., Klossner, D., Colgate, B., & Cantu, R. C. (2015) Annual survey of football injury research. *National Federation of State High School Associations*. https://nccsir.unc.edu/wp-content/uploads/sites/5614/2013/10/Annual-Football-2014-Fatalities-Final.pdf

Lau, B. C., Kontos, A. P., Collins, M. W., Mucha, A., & Lovell, M. R. (2011). Which on-field signs/symptoms predict protracted recovery from sport-related concussion among high school football players?. *The American Journal of Sports Medicine*, 39(11), 2311-2318. doi: 10.1177/0363546511410655

Lau, B. S., Lovell, M. R., Collins, M. W., & Pardini, J. (2009). Neurocognitive and symptom predictors of recovery in high school athletes. *Clinical Journal of Sports Medicine*, 19(3), 216-221. doi: 10.1097/JSM.0b013e31819d6edb

Lee, Y. M., Odom, M. J., Zuckerman, S. L., Solomon, G. S., & Sills, A. K. (2013). Does age affect symptom recovery after sports-related concussion? A study of high school and college athletes. *Journey of Neurosurgery: Pediatrics*, 12, 537-544. doi: 10.3171/2013.7.PEDS12572

Lincoln, A. E., Caswell, S. V., Almquist, J. L., Dunn, R. E., Norris, J. B., & Hinton, R. Y. (2011). Trends in concussion incidence in high school sports: a prospective 11-year study. *The American Journal of Sports Medicine*, 39(5), 958-963. doi: 10.1177/0363546510392326

Linder, S. M., Lear, A., Linder, J., Lake, A., Brier, C., McGrath, M., Cruikshank, J., Figler, R., & Alberts, J. L. (2021). Symptom recovery and the relationship between post-injury symptom scores and neurocognitive performance in athletes with sports-related concussion. *Journal of Concussion*, 5, 1-9. doi: 10.1177/20597002211018063

Lovell, M. R., Collins, M. W., Iverson, G. I., Field, M., Maroon, J. C., Cantu, R., Podell, K., Powell, J. W., Belza, M., & Fu, F. H. (2003). Recovery from mild concussion in high school athletes. *Journal of Neurosurgery*, 98, 295-301.

Marar, M., McIlvain, N. M., Fields, S. K., & Comstock, R. D. (2012). Epidemiology of concussions among united states high school athletes in 20 sports. *The American Journal of Sports Medicine*, 40(4), 747-755. doi:10.1177/0363546511435626

McCrea, M. et al. (2003). Acute effects and recovery time following concussion in collegiate football players the NCAA concussion study. *Journal of the American Medical Association*, 290(19), 2556-2563.

McCrea, M., Barr, W. B., Guskiewicz, K., Randolph, C., Marshall, S. W., Cantu, R., Onate, J. A., & Kelly, J. P. (2005). Standard regression-based methods for measuring recovery after sport-related concussion. *Journal of the International Neuropsychological Society*, 11, 58-69. doi: 10.1017/S1355617705050083

McCrea, M., Guskiewicz, K. Randolph, C., Barr, W. B., Hammeke, T. A., Marshall, S. W., Powell, M. R., Ahn, K. W., Wang, Y., & Kelly, J. P. (2012). Incidence, clinical course, and predictors of prolonged recovery time following sports-related concussion in high school and collegiate athletes. *Journal of International Neuropsychological Society*, 18, 1-12. doi: 10.1017/S1355617712000872

McCrea, M., Randolph, C., Barr, W. B., & Hammeke, T. A. (2012). Incidence, clinical course, and predictors of prolonged recovery time following sport-related concussion in high school and college athletes. *Journal of the International Neuropsychological Society*, 18, 1-12. doi: 10.1017/S1355617712000872

McCrory, P., Johnston, K., Meeuwisse, W., Aubry, M., Cantu, R., Dvorak, J., Graf-Bauman, T., Kelly, J., Lovell, M., & Schamasch. (2005). Summary and agreement statement of the 2nd international conference on concussion in sport, prague 2004. *British Journal of Sports Medicine,* 39(suppl I): i78-i86. doi: 10.1136/bjsm.2005.018614

McCrory, P., Meeuwisse, K., Johnston, K., Dvorak, J., Aubry, M., Molloy, M., & Cantu, R. (2009) Consensus statement on concussion in sport – the 3rd international conference on concussion in sport held in zurich, november 2008. *South African Journal of Sports Medicine*, 21(2), 36-46.

McCrory, P., Meeuwisse, W., Aubry, M., Cantu, B., Dvorak, J., Echemendia, R., Engebretsen, L., Johnston, K., Kutcher, J., Raftery, M., Sills, A., Benson, B., Davis, G., Ellenbogen, R., Guskiewicz, K., Herring, S. A., Iverson, G., Jordan, B., Kissick, J., . . . Turner, M. (2013). Consensus statement on concussion in sport – the 4th international conference of concussion in sport held in zurich, november 2012. *Journal of Science and Medicine in Sport*, 16, 178-189. http://dx.doi.org/10.1016/j.jsams.2013.02.009

McCrory, P., Meeuwisse, W., Dvorak, J., Aubry, M., Bailes, J., Broglio, S., Cantu, R. C., Cassidy, D., Ellenbogen, R., Emery, C., Engebretsen, L., Fedderman-Demont, N., Giza, G. C., Guskiewicz, K. M., Herring, S., Iverson, G. L., Johnston, K. M., Kissick, J., . . . Vos, P. E. (2017). Consensus statement on concussion in sport – the 5th international conference on concussion in sport held in berlin, October 2016. (2017). *British Journal of Sports Medicine*, 51(11), 838-847.

Meehan III, W. P. (2011). Medical therapies for concussion. *Clinical Journal of Sports Medicine*, 30, 115-124. doi: 10.1016/j.csm.2010.08.003

Meehan III, W. P., d'Hemecourt, P., Collins, C. L., & Comstock, R. D. (2011). Assessment and Management of Sport-related concussions in united states high schools. *American Journal of Sports Medicine*, 39(11), 2304-2310. doi: 10.1177/0363546511423503

Meehan III, W. P., Taylor, A. M., & Proctor, M. (2011). The pediatric athlete: younger atheltes with sport-related concussion. *Clinical Journal of Sports Medicine*, (30), 133-144. doi: 10.1016/j.csm.2010.08.0040278-5919/11/$

Meehan, W. P., Mannix, R., Monuteaux, M. C., Stein, C. J., & Bachur, R. G. (2014). Early symptom burden predicts recovery after sport-related concussion. *Neurology*, 83, 2204-2210.

Nelson, L. D., Guskiewicz, K. M., Barr, W. B., Hammeke, T. A., Randolph, C., Ahn, K. W., Wang, Y., & McCrea, M. A. (2016). Age differences in recovery after sport-related concussion: a comparison of high school and collegiate athletes. *Journal of Athletic Training*, 51(2), 142-152. doi: 10.4085/1062-6050-51.4.04

Notebaert, A. J. & Guckiewicz, K. M. (2005). Current trends in athletic training practice for concussion assessment and management. *Journal of Athletic Training*, 40(4), 320-325.

O'Connor, K. L., Baker, M. M., Dalton, S. L., Dompier, T. P., Broglio, S. P., & Kerr, Z. Y. (2017). Epidemiology of sport-related concussions in high school athletes: national athletic treatment, injury and outcomes network (nation), 2011-2012 through 2013-2014. *Journal of Athletic Training*, 52(3), 175-185. doi: 10.4085/1062-6050-52.1.15

Ommaya, A. K. & Gennarelli, T. A. (1974). Cerebral concussion and traumatic unconsciousness correlation of experimental and clinical observations on blunt head injuries. *Brain*, 97, 633-654.

Prien, A., Grafe, A., Rossler, R., Junge, A., & Verhagen, E. (2018). Epidemiology of head injuries focusing on concussions in team contact sports: a systematic review. *Sports Medicine*, 48, 953-969. doi: 10.1007/s40279-017-0854-4

Putukian, M., D'Alonzo, B. A., Campbell-McGovern, C. S., & Wiebe, D. J. (2019). The ivy league – big ten epidemiology of concussion study: a report on methods and first findings. *The American Journal of Sports Medicine*, 47(5), 1236-1247. doi: 10.1177/03635465119830100

Putukian, M., Riegler, K., Smalfe, S., Bruce, J., &Echemendia, R. (2021) Preinjury and postinjury factors that predict sports-related concussion and clinical recovery time. *Clinical Journal of Sports Medicine*, 31(1), 15-22. doi: http://dx.doi.ord/10.1097/JSM.0000000000000705

Reports of the Sports Medicine Committee. (1991). Guidelines for the Management of Concussion in Sports. *Denver, CO: Colorado Medical Society*.

Rose, S. C., Fischer, A. N., & Heyer, G. L. (2015). How long is too long? the lack of consensus regarding the post-concussion syndrome diagnosis. *Brain Injury*, 29, 798-803. doi: 10.3109/02699052.2015.1004756

Schilling, S., Mansour, A., Sullivan, L., Ding, K., Pommering, T., & Yang, J. (2020) Symptom burdens and profiles in concussed children with and without prolonged recovery. *International Journal of Environmental Research and Public Health*, 17, 351-361. doi: 10.3390/ijerph17010351

Symonds, C. P. (1962). Concussion and its sequalae. *Lancet*, 1, 1-5.

Teel, E. F., Marshall, S. W., Shankar, V., McCrea, M., & Guskiewicz, K. M. (2017). Predicting recovery patterns after sports related concussion. *Journal of Athletic Training*, 52(3), 288-298. doi: 10.4085/1062-6050-52.1.12

Thomas, D. J., Coxe, K., Hongmei, L., Pommering, T. L., Young, J. A., Smith, G. A., & Yang, J. (2018) Length of recovery from sports-related concussions in pediatrics patients treated at concussion clinics. *Clinical Journal of Sports Medicine*, 28(1), 56-63. doi: http://dx.doi.org/10.1097/JSM.0000000000000413.

Tsushima, W. T., Siu, A. M., Ahn, H. J., Chang, B. L., & Murata, N. M. (2019). Incidence and risk of concussions in youth athletes: comparisons of age, sex, concussion history, sport, and football position. *Archives of Clinical Neuropsychology*, 34, 60-69.

Walker, A. E. (1973). Mechanisms of cerebral trauma and the impairment of consciousness. *Neurological Surgery*, 2, 936-949.

Ward, A. A. (1964). The physiology of concussion. *Clinical Neurosurgery*, 12, 95-111.

, R. M., Puetz, T. W., Giza, C. C., & Broglio, S. P. (2015). Concussion recovery time among high school and collegiate athletes: a systematic review and meta-analysis. *Sports Medicine*, 45(6), 893-903. doi:10.1007/s40279-015-0325-8

World Health Organization. (2003). The icd-10 classification of mental and behavioural disorders: diagnostic criteria for research. (10th ed.)

Zuckerman, S. L., Yengo-Kahn, A. M., Buckley, T. A., Solomon, G. S., Sills, A. K., & Kerr, Z. Y. (2016). Predictors of postconcussion syndrome in collegiate student-athletes. *Neurosurgical Focus*, 40(4), 1-10. doi: 10.3171/2016.1.FOCUS15593

APPENDIX

APPENDIX A

IRB Letter of Exclusion

IRB
INSTITUTIONAL REVIEW BOARD
Office of Research Compliance,
010A Sam Ingram Building,
2269 Middle Tennessee Blvd
Murfreesboro, TN 37129

MIDDLE TENNESSEE STATE UNIVERSITY

IRBN014 – NON-RESEARCH DESIGNATION NOTICE

Monday, March 26, 2018

Principal Investigator	Joshua T. Haley (Student)		
Faculty Advisor	Don Belcher		
Co-Investigators	None		
Investigator Email(s)	joshuahaleyatc@yahoo.com; don.belcher@mtsu.edu		
Department	Health and Human Performance		
Proposal Title	Do Reported Concussion Symptoms Indicate Extended Time from Play in High School Athletes?		
NEW IRB ID	**18-0227**	*OLD IRB ID*	**N/A**

Dear Investigator(s),

The above identified research proposal has been reviewed by the MTSU Institutional Review Board (IRB). Based on the information provided to the IRB, this study either does not involve the data collection from living human subjects, or your proposed data collection is not done using a systematic approach to derive generalizable knowledge, or both. The proposed study does not fit the definition of human subjects' research as stated by OHRP (45 CFR 46.102. Since the protocol only involves publicly available de-identified data *(45 CFR 46.102f - non-human subjects)*, it is therefore **EXCLUDED** from IRB review and oversight.

Although this study is excluded from the IRB's oversight, we encourage you to adopt best practices in your research, which includes: informed consent; autonomy to participate/decline or to withdraw without retribution; and the right remain anonymous, for all those who interact with you during this study.

We appreciate your time and we wish you very best with your proposal.

Sincerely,

Institutional Review Board
Middle Tennessee State University