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Cognitive Effects of Concussions in Collegiate Athletes

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Walden University
2019

Abstract

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BS, Norwich University, 1995

Dissertation Submitted in Partial Fulfillment

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Clinical Psychology

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Abstract

There are approximately 1.6 and 3.8 million sports-related concussions each year in the United States (Langlois, et al. 2006). However, there are few studies examining the impact of multiple concussions among collegiate athletes, especially female athletes. Over the past decade, there has been a paradigm shift with the ImPACT neuro-battery assessment tool, which is administered to athletes' pre-season as a baseline test and then re-administered upon a possible concussion, thus, comparing the two results. For this study, the focus was on the biological and psychological aspects of the Biopsychosocial Model. Secondary data from 49 college athletes was examined. The results in this study provided evidence that post-neurocognitive assessment scores, based on the ImPACT, deviated from initial baseline scores after multiple concussions, indicating there were significant differences among the values of baseline, post injury 1, and post injury 2. The results from the study can be used by coaches and athletic directors to guide their recommendations for students' return to play.

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Dedication

This dissertation is dedicated to my biggest supporter, my wife, Joan. Without her unwavering support, this would have never have been possible. I will forever remember her encouraging words and energy that helped me get to the finish line.

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Chapter 1: Introduction to the Study

Introduction

For more than a decade, concussion awareness has been at the forefront of media coverage as well as medical literature, as both have reported an exponential rise of this commom problem (Upshaw et al., 2012). For over a decade, the topic of concussions among the athletic community has sparked much research and has risen to the forefront in a negative manner (Valasek, 2012). Incidence rates of 300,000 concussions annually have been reported by the Centers for Disease Control and Prevention (CDC) annually. Since the inception of concussion education programs where individuals have become more knowledgable over the concussion topic, the annual incidence rate of sports-related concussions is closer to 1.6-3.6 million (Valasek, 2012).

The study used secondary archival data to determine if there is a deviation in neurocognitive scores from the initial baseline line test to post-concussion test because of multiple concussions in college-aged athletes. The findings from the neurocognitive scores can provide additional information to healthcare professionals and others, thus, aiding the medical and sports communities on how to precede to a path of recovery via neurocognitive assessments such as ImPACT (ImPACT Applications Inc., 2018). This neurocognitive screening tool which is scientifically validated for concussion management will be another addition for many athletes and professionals alike such as clinical psychologists and neuropsychologists. Just like psychologists who test cognitive capacities via intelligence testing from a WISC-V or WAIS-IV, the ImPACT neurocognitive assessment can also measure attention span, working memory, attention span, and non-verbal just like subtests of an intelligence test, thus, providing valuable cognitive information for psychologists to disseminate to others. This study explored the number of concussions as they relate to a specific sport, sex, and age of the college athlete. Presently, most of the research on sports-related concussions thus far has been directed towards the National Football League (NFL), while little research has been done at the collegiate level even though the ImPACT tool is routinely administered. ImPACT was developed to provide useful information to assist qualified practitioners in making sound return to play decisions following concussions.

Social implications within the realm of positive change such as acknowledging the severity of sports-related concussions need to be addressed through awareness and education. Concussion education in the United States, specifically at the college level, is dictated by the individual university on how they want to proceed with the breadth and depth of concussion education. As a result, information college athletes may receive may be inconsistent and vary greatly (Kroshus and Baugh, 2016). There needs to be a systematic approach to educating our communities (i.e. parents, coaches, school systems, health care professionals, students) that is universal in nature. Concussion education can support the interdiciplinary community to view concussions on an individual basis, to better understand the risk factors associated with sports-related head trauma, and potentially can lead to greater identification and risk factors. Now parents, coaches, psychologists, and other health professionals, by examining an athletes' baseline test scores on an ImPACT test pre-concussion and then administer the ImPACT test subsequent times post-concussion. This valuable information can help coaches and players on making more informed decisions in return-to-play protocols for athletes, thus preventing a premature return back to the sport.

Background of the Study

Through assessment tools and medical interventions, professionals have developed a greater understanding of concussons over time (Valasek, 2012). However, the full comprehension of concussions has only begun to be explored, specifically its long-term effects on athletes (Valasek, 2012). When sports-related concussions were first noticed, they were relatively ignored because these concussed symptoms would eventually diminish and the athlete's cognitive state returned back to its pre-concussed state even when the athlete reported symptoms (Lidvall et al., 1974).

Over the past decade, there have been International Conferences on Sports Concussions in 2001, 2004, 2008, 2012, and 2016 respectively, where experts converge from all over the world to provide new guidelines and recommendations on sports-related injuries and concussions (IOM, 2014). Collectively, the decision-making processes and recommendations setforth by the professionals at these conferences have become the framework on how concussions are now viewed (IOM, 2014). It was not until 2010, that concussion recommendations that were tailored to children and adolescents in the Academy of Pediatrics (Halstead and Walter, 2010). Since 2010, most research continues to focus on sports-related concussions and head injuries in the National Football League (Brooks et al., 2013). While most of the literature is concentrated to this particular demographics, there have been more research, not to the extent as the NFL, on collegiate sports as well as the military. The one common theme that has not changed since the inception of concussion awareness, is the operational definition of a concussion. The definition of a concussion by many authors and researchers is “A complex pathophysiological process affecting the brain, induced by traumatic biomechanical forces, that may or may not involve loss of consciousness” (Aubry et al., 2002; Cubon et al., 2011; Shultz et al., 2004; Upshaw et al., 2012). Broglio et al., (2017) noted the same theme when he examined college athletes and US military service members.

Although sports-related concussions have been examined at the professional level, there seems to be a shortage of literature as it pertains to psychological consequences and the cognitive faculties affected by concussions, among Division III athletes and high school athletes. In 2015a, Kroshus et al., examined a series of literature reviews exploring many topics such as concussion under-reporting from coaches, pressure to return athletes prematurely back into the game, and concussion education combined with social norm theory. Collectively, they demonstrated the importance of this topic as it pertains to the clinical realm, specifically psychologists and how they approach these diminshed cognitive faculties and move forward with prescribed protocols. This is significant for many reasons: under-reporting or pressure from coaches to get athletes back in the game as soon as possible, teammates, fans, and parents for similar reasons (Kroshus et al., 2015b). Baugh et al., (2014) mentioned symptom reporting or there lack of one year prior to the three Kroshus (2015abc) articles. Baugh et al. (2014) noted that undereporting had been an epidemic due to ignorance, of signs and symptoms, removal from play, pressure from coaches and teammates, and fear of being cut from the team. As a result of this under-reporting and pressure to return to play, 50% of concussions go undiagnosed which creates a neurological nightmare for diagnosing psychologists to make informed decisions (Baugh et al., 2015). As these concussed athletes continue to participate under concussed conditions, they put themselves at greater risk of further cognitive damage or worse (Kroshus et al., 2015a). Developing strategies for players, coaches, teammates, and parents who will support players to come forward and report symptoms is only one form of risk management, while the other is education (Kroshus et al., 2015b). Education alone is not the cure for concussion reporting and in a separate literature review conducted by Kroshus et al., (2015c), it was noted that there was a caveat to education; expanding social norm theory. The social norm theory as it pertains to concussions places emphasis on teammate reporting rather than the individual and that teammates would be more objective in reporting than the individual themselves (Kroshus et al., 2015c) It is essentially a "battle buddy" like in the military world. In the military, you and your "battle buddy" are rsponsible for one another and therefore, look out for each other. When one does not recognize the signs and symptoms themselves, an objective party intervenes. Together, these concepts would help contribute to professional knowledge and practice among the sports community while simultaneously helping psychologists make better informed decisions based on the athletes' psychological consequences as a result of a sports-related concussion. Unfortunately, many individuals are still not aware of the of risks when players return prematurely to the game or continue to play unknowingly that they have a concussion. After the overt signs and symptoms are addressed, the psychologist can then address the covert signs and symptoms that athletes may not be able to handle by themselves.

Problem Statement

Sports-related concussions have become the focal point of discussion for many health professionals including psychologists, particularly the negative impacts they have on children and adolescents (McCrory et al., 2009). Despite increased awareness of concussions in children and adolescents through literature reviews and professionals in the field, there is still not a universal consensus on an operational definition of a concussion (Gordon et al., 2006). Despite mandated concussion programs, (Kroshus et al., 2013) there is limited empirically-based literature on sports-related concussions at the college level along with assessments of college athletes who sustain sports-related head injuries.

The actual number of sports-related concussions each year varies according to the Sports Concussion Institute (2012). A potential barrier in the variability can be because of the Health Insurance Portability and Accountability Act (HIPAA), where colleges and coaches do not have to release concussion numbers and Protected Health Information (PHI) cannot be disclosed without the permission of the athlete. So, concussions do not have to be disclosed without a bilateral consent between both parties which is no different than obtaining permission from your physician in order to have a two-way conversation. The motivation behind the study is that sports-related concussions are problematic on many levels that can have lasting effects on our youth. If more concussion awareness programs were developed to provide more education around concussions and their consequences, then perhaps sports organizations, institutions, clubs, school systems, and others could take a proactive approach rather than a reactive approach. Creating such programs could dictate protocols, practice guidelines, and other safety measures to reduce and perhaps prevent concussions.

In addition to male college athletes, the number of females currently participating in sports has risen over time. To date, research on concussions has been geared toward male athletes, thus wondering if females are at greater risk than their male counterparts for concussions in similar sports. According to the Sports Concussion Institute (2012), soccer poses a 50% chance of being concussed for females, which is the highest among all the sports. This study explores if there is a distinction between sexes, specifically if female athletes have poorer outcomes on neuropsychological testing post injury than male athletes.

Research Questions and Hypothesis

The premise of this study is to determine if there are deviations in baseline scores and post-injury scores based on neurocognitive testing based on sex, sport, multiple concussions, age, or all the variables. Indicated below are the research questions and the corresponding hypotheses for this study. Corresponding Chapters 2 and 3 offer greater detail and explanation of the following research questions, hypotheses, and quantitative analysis.

RQ1: Do post-neurocognitive assessment scores, based on the ImPACT, deviate from initial baseline scores after multiple concussions?

$H_1$1; Multiple concussions scores significantly deviate from initial baseline scores.

$H_0$1: Multiple concussions do not significantly deviate from initial baseline scores.

RQ2: Do post-ImPACT computerized neurocognitive assessment scores deviate from initial baseline scores in certain sports (baseball. basketball, football, ice hockey, lacrosse, rugby, soccer, volleyball, wrestling)?

$H_1$2: Scores of certain sports significantly deviate from initial baseline scores.

$H_0$2: Scores of certain sports do not significantly deviate from initial baseline scores.

RQ3: Do post-ImPACT computerized neurocognitive assessment scores deviate from initial baseline scores in certain sexes?

$H_1$3: Certain sexes significantly deviate scores from initial baseline scores.

$H_0$3: Certain sexes do not significantly deviate scores from initial baseline scores.

RQ4: Do post-ImPACT computerized neurocognitive assessment scores deviate from initial baseline scores in specific ages (18-24)?

$H_1$4: Specific ages significantly deviates scores from initial baseline scores.

$H_0$4: Specific ages do not significantly deviate scores from initial baseline scores.

RQ5: Do post-ImPACT computerized neurocognitive assessment scores deviate from initial baseline scores due to all the above variables?

$H_1$5: All of the above variables significantly deviate scores from initial baseline scores.

$H_0$5: All of the above variables do not significantly deviate scores from initial baseline scores.

Purpose of the Study

The purpose of this quantitative analysis of secondary data is to identify whether or not there is a correlation between assessment scores as predicted by number of concussions, demographic variables (age and sex), type of sport, and/or all the aforementioned variables in college-aged athletes. The dependent variable (DV) is the change in the assessment score and the independent variables (IV) are number of concussions, type of sport, raw age, and sex.

Theoretical Framework

The theoretical framework of the study is based on George Engel's "biopsychosocial model," which incorporates the theory of illness and healing (Cohen and Brown, 2010). George Engel noted that such actions at the biological, psychological, and sociocultural level possess an intricate interaction in which these connections determine process and outcomes of care (Greenberg, 2005)). This perspective effects many levels of functioning in the mind, body, and environment from the cellular to organ system to person, family, and society, thus, providing a more global approach to comprehending the disease process as multi-layered process of functioning to include practitioner-patient relationship (Cohen and Brown, 2010).

The clinical approach using this model is used to integrate all of aspects noted above into a single treatment plan with the patient at the core of the plan (Greenberg, 2005). Adler (2009) describes the model as the study of signs and symbols and how they relate between patient and their environment and this model relates to sports-related concussions because of the patient's demographics.

Currently, terms such as prognostic models have been used to describe concussions/traumatic brain injuries. This prognostic model is geared toward clinical practices where the risks to a specific condition or disease are analyzed in an individual at the ground level by viewing information gathered from many individuals together by getting an aerial view of the problem (Silverberg et al., 2015). As early as 2008, Steyerberg et al. were examing a prognostic model for traumatic brain injuries using three clinical criteria: age, Glasgow Coma Scale, and pupillary reactivity. This information in turn, could be used in clinical settings by psychologists in their decision making while educating family members as well. This prognostic model incorporates a multivariable approach which eliminates a single predictive variable and allows for mutiple predictors in order to form a better clinical prediction for an individual (Silverberg et al., 2015). Silverberg et al., (2015) acknowledged limitations in their study with mild traumatic brain injury individual and noted that there is no existing mutivariable prognostic model that can predict outcomes for these individuals. However, Silverberg et al., (2015) presented another way to conceptulize brain injuries by incorporating multiple biopsychosocial factors such as sex, pre-injury mental health issues, psychological distress, post-injury cognitive impairments, genetics, MRIs, psychosocial variables, serum biomarkers, and preinjury vulnerability in young children. The prognostic model is the closest model to formulating a clear precise definition of a concussion. Carney et al., (2014) noted that by drawing from all multidisciliary facets a clear definition of a concussion could be reached. This aerial view of brain injuries is yet another way for future implications on how we clinically approach this problem in practice.

The NFL currently incorporates biopsychosocial characteristics within their neurocognitive testing when assessing each player during the initial testing process (Solomon and Hasse, 2008). Thus, it affords the NFL to address characteristics such as medical, psychiatric, chemical dependency, concussion, anxiety and depression disorders, and symptom variables, and the relevance of each to baseline neurocognitive test scores (Solomon and Hasse, 2008).

The focus of this research is restricted to the biological and psychological aspects of the Biopsychosocial Model. The biological aspect is focused to physiological events such athletes who pose challenges recalling if they have had a concussion, even when there was clear evidence of loss of consciousness, give the practitioner a window into their psychological condition and inner struggles.

Definition of Terms

Chronic traumatic encephalopathy (CTE): "Degenerative disease that is progressive in nature found in individuals with repetitive head trauma such as concussions and subconcussive blows to the head" (Gavett et al., 2011; McKee et al, 2009; Stern et al., 2011).

Concussion: - "A complex pathophysiological process affecting the brain, induced by traumatic biomechanical forces, that may or may not involve loss of consciousness" (Aubry et al., 2002; Cubon et al., 2011; Shultz et al., 2004; Upshaw et al., 2012).

Concussion Classification (Grading): - "grade 1-confusion only, grade 2-confusion and post-traumatic amnesia, and grade 3 and 4-loss of consciousness and the three most common grading systems are American Academy of Neurology, Kelly et al, (1991) and Cantu grading systems" (American Academy of Neurology, 1997; Cantu, 1986, 2001; Halstead et al., 2010; Johnston et al., 2001; Kelly et al., 1991; McCrory et al., 2009). ImPACT: - "Neurocognitive baseline testing that can objectively determine an athlete's injury from a concussion by comparing the results to the baseline and again to the post-injury tests, thus tracking the data and avoiding a premature return to play by the team's physician" (Lovell et al., 2012).

Assumptions

There are several assumptions to this study. First, an assumption is that a concussion can be quantitatively measured through instrumentation and statistics, and that the ImPACT assessment tool is a valid measure of concussions. Second, there is an assumption that age, gender, and sport significantly impact the effect a concussion has on an individual. Third, it is assumed that the data collected was retrieved by competent and reliable individuals. A final assumption is that ImPACT assessment tool is a valid measure of the cognitive sequelae of concussions.

Limitations

There are also limitations to this study as well. The first limitation is that individuals were administered only one neurocognitive battery to determine cognitive deficits, thus, there is only one baseline per athlete to be viewed. In an ideal situation, the administration of multiple batteries would be administered to provide more information to make a return-to-play decision for an athlete. The second limitation is that the sample size in this proposed study is smaller than preferred due to the size of the university's athletic department. A third limitation is that the ImPACT scores should be examined from a longitudinal approach rather than one baseline test and subsequent tests after an injury. Also, preexisting archival data is being utilized for this non-experimental study. As a result, the fourth limitation is that the author cannot control any of the variables in this non-experimental study. In addition, the following is a list that this researcher does not have access to: fMRIs, formal clinical interviews, familial histories, GPAs, academic performance, or discipline records. A longitudinal approach would provide a time series account of scores across a 4-year period that could be further examined. Also, this researcher did not have access to an athlete's file for a formal record review which would include academic grades in college, medical records, other types of evaluations if applicable, and prior high school records. Finally, this study did not control for other head injuries outside of the university setting. These limitations can provide useful information to athletic directors, health professionals, coaches, and parents, and may be considered in future research.

Delimitations

The study attempts to discover if there are cumulative effects from multiple concussions among collegiate level athletes. Based on the data gathered from a Division III university, athletes were sorted by specific sport, sex, and age. Also, most of Division III athletes do not go on to play professional sports.

Significance of the Study

Over the past decade, there has been a paradigm shift for a greater increased awareness and understanding of concussions and how they directly relate to a level of brain injury. This greater level of understanding has led health professionals to provide further evaluations before recommending their non-professional athletes return to play, thus, preventing lifelong consequences.

Post-concussion syndrome can have lifelong cognitive effects on an athlete, which can be permanent and disabling (King, 2003). Most individuals recover within a 3-month timeframe, however, there is one-third of the population that does not possess such resiliency and go well beyond the 3-month timeframe which can lead to permanent disabilities (King, 2003). Thus, cognitive deficits may remain indefinite, more specifically within the realm of information processing (King, 2003). Long-term effects of sports-related repetitive head impacts has been demonstrated over the course of a single football season showed changes in white matter associated with recurring helmet impacts and continued 6 months following no contact (Bazarian et. al., 2014). As a result, there can potentially be a correlation between repetitive head impacts and white matter changes (Bazarian et. al., 2014). Also, while an athlete is recovering from their initial concussion, and simultaneously receive a second head impact, the results can be catastrophic as in Second Impact Syndrome, which has claimed 30-40 deaths over the past decade (ImPACT Applications Inc., 2018).

This study was designed to contribute in educating health professionals, coaches, students, parents, and others working with adolescents of examining the way concussions are looked at and approached. The standardized protocol currently in place states that athletes begin at Stage 1 for 24 hours before moving on to Stage 2 (Rivara and Graham, 2014). Nearly one-third of athletes who have been cleared by professionals and appear to be symptom-free failed at least one neurocognitive test, thus indicating that post-neurocognitve testing may need to be administered (Rivara and Graham, 2014). More specifically, the results of this study may give healthcare providers and others who work with athletes another way of looking at return to play following one or multiple concussions. College coaches, administrators, athletes, and health providers can use this information as a conduit with existing approaches in concussion management. The significance of concussion awareness is important to future athletes in the United States and around the world to promote positive social change. The significance of National public health concern has reached Washington D.C. where President Obama delivered opening remarks at the White House Healthy Kids & Safe Sports Concussion Summit in the East Room of the White House, May 29, 2014 (https://www.whitehouse.gov/blog/2014/05/29/president-obama-hosts-healthy-kids-and-safe-sports-concussion-summit). Therefore, the results of this study may contribute to information about concussion awareness in athletic settings, as well as when athletes should return to playing sports following one or multiple concussions. The significance of concussion awareness, cumulative effects, and gender differences are important to future athletes in the United States and around the world by promoting better social change through improved behavior and health.

Chapter 1 of this study provides an introduction and background of the study along with the problem statement and research questions and hypothesis. In addition, the purpose of the study, theoretical framework, assumptions, limitations, delimitations, and significance of the study are provided as well. Chapter 2 reviews the use of the Biopsychosocial Model with peer reviewed literature on concussions and their neuro-cognitive consequences. In addition, Chapter 2 examines multiple concussion grading systems used in the past along with gender differences among concussed athletes.

Chapter 2: Literature Review

Introduction

The purpose of this study is to contribute to the conceptualization of sports-related injuries. This chapter provides a detailed discussion of themes in the literature review such as (a) comprehensive assessments of concussions, (b) identification of concussions, (c) risk factors, (d) sports, and (e) gender. The theoretical framework for the study is based on George Engel's "biopsychosocial model," which incorporates the theory of illness and healing. This interdisciplinary model integrates health and wellness with biological, psychological, and sociocultural aspects or mind, body, and environment. For the purpose of this study, the focus is on the biological and psychological aspects of the model. The biological component to this model is focused primarily on the relationship between psychological processes and underlying physiological events. More specifically, damage to the brain tissue as a result of a concussion can potentially impact the psychological health of an athlete (IOM, 2014).

Primary research was obtained through the online databases of Walden University. EBSCO host research databases included MEDLINE and ProQuest. Research was also obtained through credible Internet sites such as PubMed, Google Scholar, the National Insitutes of Health (NIH), Center for Disease Control (CDC) and World Health Organization (WHO). The following monograph was consistently used throughout this review: Sports-Related Concussions in Youth; Institute of Medicine and National Research Council.

Utilization of the aforementioned resources was done by targeting specific keywords in the electronic databases with terms such as “sports” and “injuries” and “epidemiology” and “concussions” between the years 2010 to 2017. The targeted words and years yielded literature results that spanned across all sports, ages, and gender. The selection of these major resources afforded the most current scholarly literature to date on the selected topic. The literature review was organized and conducted on search terms Biopsychosocial Model, concussions, neuropsychological consequences of concussions, neurocognitve testing, neuroimaging, and concluding with recommendations and future research.

Another source that informed the literature review was the monograph published by the Health and Medicine Division (HMD), a division of the National Academies of Sciences, Engineering, and Medicine (the National Academies), formally the Institute of Medicine in 2014. The Institute of Medicine (IOM) was established in 1970 by the National Academy of Sciences as a checks and balances system to protect the public welfare using expert consensus from its members and other professionals (IOM, 2014). In 2014, the Institute of Medicine-National Research Council (IOM-NRC) Committee on Sports-Related Concussions in Youth published a monograph which synthesized the strengths, weaknesses, and results or epidemiologic, clinical, and sports-related concussion research from years 1988 to 2013 (IOM, 2014). This expert panel review was supported by contracts between the National Academy of Sciences and the Centers for Disease Control and Prevention (CDC); the CDC Foundation with support from the National Football League; the Department of Defense; the Department of Education; the

Health Resources and Services Administration; the National Athletic Trainers' Association Research and Education Foundation; and the National Institute of Health (IOM, 2014).

In addition to the literature being based on Biopsychosocial Model which served as a guide in the organization of the literature, this model also aided in the selection of the following variables as they relate to sports-related injuries: concussions, neuropsychological consequences of concussions, neurocognitve testing. The biopsychosocial approach (Engel, 1980) in clinical application discussed self-awareness from a physician's prospective while the Institute of Medicine (IOM, 2014) discussed self-awareness from the athlete's prospective as a key component to combat concussions as well as risk factor recognition and a multi-modal approach in treatment.

Evolution of Sports-Related Concussions

For more than a decade, sports-related concussions have become a controversial topic of many including athletes, coaches, psychologists, physicians, and parents, especially in youth athletes (IOM, 2014). Concussions are synomous with the National Football League (NFL) and the pending lawsuits associated with them. While the spotlight has been placed on the National Football League, another group of demographics has been affected by sports-related concussions which are adolescent athletes (IOM, 2014).

Incidence rates among this population for sports-related concussions has risen in the past decade. Tommasone and McLeod (2006) explored incidence rates between 1985-2000 in eight contact sports: American football, boxing, ice hockey, judo, karate, tae kwon do, rugby, and soccer. In 1985, Tommasone and McLeod (2006) recognized there was a a concern with adolescent male concussion incidence rates, especially noting that ice hockey had the highest rate while soccer had the lowest for this population. A decade later Pfister et al. (2016) found that incidence rates of concussions in adolescents was highest in football, rugby, and ice hockey, while volleyball and cheerleading yielded the lowest rates. Collectively, over many decades of research, contact sports remain a greater risk for concussions compared to noncontact sports (Pfister et al., 2016).

Since the Tommasone and McLeod study in 2006 research has expanded to a broader spectrum of sports. In 2015, Zuckerman et al. examined the epidmiology of sports-related concussions in NCAA athletes from 2009-2010 to 2013-2014: incidence, recurrence, and mechanisms and found that 68% of concussions were from player contact. Among the sports that lead to concussions, men's wrestling, men's and women's ice hockey, along with football, and men's lacrosse have the highest rates (Zuckerman et al., 2015). Two years later, O'Conner et al. (2017) examined the epidemiology of sports-related concussions in high school athletes from 2011-2012 through 2013-2014 and found similar findings as Zuckerman et al. (2015) that when spanning across multiple sports, they reported football, boys' lacrosse, and girls' soccer had the highest incidence rates. When examing studies from decades ago and comparing them to the present, the only difference is that there are an array of other sports that need attention when it comes to concussion incidence rates.

Most of the research on sports-related concussions and head injuries has been focused on the National Football League (Brooks et al., 2013). In order to visualize the progression conceptualize of concussion science and the NFL, Petchesky (2013) created a timeline, a synopsis of which is shown in Table 1. This timeline informs the proposed study because it demonstrates and highlights the importance of short and long term effects of concussions. In addition, it points out the scope of the problem along with the personal and societal costs of head injuries. Furthermore, this timeline demonstrates that sports-related concussions posed threats to athletes since the 1930s and nearly a century later, head injuries in sports are having negative impacts on athletes.

YEAR	**INCIDENCES INVOLVING CONCUSSIONS THROUGHOUT THE YEARS**
1933	NCAA's medical handbook addressed concussions reporting them as being taken too lightly and that players should not return to play for at least 48 hours.
1937	American Football Coaches Association meeting addressed concussed players should be removed from game immediately.
1952	New England Journal of Medicine reported players with three concussions should leave the game indefinitely.
1991	A concussion grading system is established and incorporated by the NCAA and high school football.
1994	NFL recognized dangers of concussions by forming the Mild Traumatic Brain Injury Committee chaired by Elliot Pellman, rheumatologist.
1995	Pellman tried to accelerate quarterback, Boomer Esiason's recovery from a concussion by having him concentrate on the computer screen.
1997	American Academy of Neurology recommended players who were knocked unconscious as a result of being concussed be removed from the game, however, the NFL rejected these guidelines.
1999	NFL's retirement board paid out millions in disability payments to former players who became disabled from cognitive decline.
2000	American Academy of Neurology found that 61% of former NFL players were concussed.
2002	Omalu, M.D. examined former NFL player, Mike Webster's brain and reported evidence of Chronic Traumatic Encephalopathy (CTE).
2003	A study showed retired football players having multiple concussions doubled their risk for depression.
2004	Omalu examined another NFL player's brain and found evidence of CTE.

2005	MTBI released findings which stated the return-to-play posed no significant risk of being concussed. A study at UNC reported that there is a direct correlation between cumulative effects and number of concussions. Omalu published his finding in the jouranl of Neurosurgery in which the NFL demanded a retraction of the article immediately. Former NFL player, Terry Long commits suicide by drinking antifreeze and later is found out to have CTE.
2006	Former NFL player, Andre Waters commits suicide by a gun shot to the head. Upon further examination by Omalu, Waters had brain tissue of an 85-year old.
2009	NFL acknowledges head trauma and the first round of lawsuits are filed from players as far back as the 1940s. NFL player, Chris Henry dies after jumping out of a moving vehicle. It is later discovered that he is diagnosed with CTE.
2010	MTBI reported to Congress that there is no correlation between CTE, athletes, and head trauma. Afterwards, MTBI is abolished and a new committee is formed. The NFL's response is to put up concussion posters in all the locker rooms and will penalize players for deliberate blows to the heads of other players.
2012	Former NFL player, Junior Seau commits suicide by inflicting a gun shot wound to the chest. Upon further examination, it is discovered his brain has CTE. Boston University studied 35 brains of deceased NFL players and discovered 34 had CTE.
2013	The lawsuits from former players suing the NFL are consolidated and settled, with the NFL paying out $765 million without admitting liability.

Source: (Petchesky, 2013).

As sports-related concussions began making their way to the forefront of importance, the NCAA and the Department of Defense (DOD) unveiled a concussion study in May 2014, with a $30 million initiative foused on safety of student-athletes and risks, treatment, and management of concussions (NCAA, 2014). The purpose of this collaboration was to inform psychologists, athletes, coaches, and parents. Among many questions are cumulative effects of concussions on adolescent athletes (Brooks et al., 2013). It was also noted that future research was needed in the area of gender and age differences and the effects of concussions in males versus females (Brooks et al., 2013; O'Conner et al., 2017; Pfister et al., 2016; Tommasone and McLeod, 2006; Zuckerman et al., 2015). The aforementioned authors noted that in addition to future research on sports-related concussions in other sports, future research was needed across levels of competition and division (O'Conner et al., 2017; Pfister et al., 2016; Tommasone and McLeod, 2006; Zuckerman et al., 2015). Finally, social change implications in the realm of culture change, specifically acknowledging the severity of sports-related concussions needed to be addressed (IOM, 2014). This included the areas of concussion education, recognition, and acceptance of the injury in order to encourage and foster the reporting of concussions, therefore implementing the appropriate concussion management guidelines (Guskiewicz and McLeod, 2011; Pfister et al., 2016; Wasserman, et al., 2016). In 2017, Broglio et al. recognized lack of consensus regarding the definition of concussion. The National Collegiate Athletic Association and the Department of Defense partnered to create the Concussion Assessment, Research and Education Consortium to further examine concussions from a microlevel, specifically clinical and neurobiological recovery in collegiate athletes and military personnel (Broglio et al., 2017). This study is the first based on a model that explored policies, procedures, and governance using a 6-month longitudinal approach to formulate recommendations (Broglio et al., 2017).

As the sports-related concussion net widens, so do more questions around sex differences and clinical recovery. The research to date on recovery time for females is much higher than males due to neck strength and injury biomechanics according to Iverson et al., (2017). This is one particular area where research is lacking.

Biopsychosocial Model

The theoretical framework for this study is based on George Engel's "biopsychosocial model," which incorporates the theory of illness and healing. This interdisciplinary model integrates health and wellness as the source of an intricate interaction between biological, psychological, and sociocultural aspects or mind, body, and environment. Breaking away from traditional biomedical and biological models, the biopsychosocial approach stressed the importance of human health and illness in their greatest capacities (Cohen and Brown, 2010).

The clinical approach to the biopsychosocial model is laid out in the hierarchy of natural systems (figure 1) (Engel, 1980). Using this as a navigation tool, the practitioner from the onset takes into consideration all information as it pertains to each of the natural system levels and its relevance when examining the patient (Engel, 1980). This information is used for additional study and care of that patient (Engel, 1980).

Each level in the hierarchy of natural systems stands for an organized whole as to justify its identity (Engel, 1980). Its identity reflects the properties and traits it possesses (Engel, 1980). The name given to each level indicates its complexity surrounding its existence in the model (Engel, 1980). Therefore, each natural system identified has such unique characteristics and properties that require additional criteria for study and a detailed unique explanation for that level and the hierarchy should be viewed as a continuum (Engel, 1980).

Solomon and Hasse (2008) examined biopsychosocial characteristics and neurocognitive test performance in National Football League players. The major constructs of Engel's biopsychosocial model through the following variables demonstrated how they may influence baseline test scores. The variables examined were medical, psychiatric, chemical dependency, learning disability/attention deficit disorder, concussion, and neurocognitive baseline test results using the ImPACT test battery (Solomon & Hasse, 2008).

In 2013, Echemendia et al. examined advances in neuropsychological assessments of sports related concussions. Engels interdisciplinary model has been used in psychological assessments by psychologists. Echemendia et al. (2013) incorporated the following seven key issues in sports-related neurological assessments: (1) the advantages and disadvantages of different neuropsychological assessment modalities; (2) the evidence for and against the current paradigm of baseline/postinjury testing; (3) the role of psychological factors in the evaluation and management of concussion; (4) advances in the neuropsychological assessment of children; (5) multi-modal assessment paradigms; (6) the role of the neuropsychologist as part of the sports healthcare team and (7) the appropriate administration and interpretation of neuropsychological tests. (p. 294).

Echemendia et al. (2013) noted that neuropsychologists utilized a multidimensional assessment model when assessing concussions because of its complexity that spans across many domains of functioning. Neuropsychologists can be eclectic as they perform neurocognitive testing, take part in psychoeducational interventions, and be an integral member of a sports team, thus drawing from all aspects of the Biopsychosocial Model (Echemendia et al. 2013).

Although no studies on sports-related concussions have been identified using the biopsychosocial model specifically, many researchers and practitioners such as Collins et al., 2014; Solomon and Hasse, 2008; Wiese-Bjornstal, 2010; Echemendia et al., 2013 subscribed to this theoretical model following sports-related concussions. These factors interact in ways that help with a greater understanding of health, illness, and delivery of services (Engel, 1980).

The biopsychosocial model is applicable to the study of sports-related concussions because the initial data received on a patient such as age, gender, residence, occupation, marital status, and so on, provide the practitioner with the foundation that can be built upon for use in additional future decisions (Engel, 1980). The clinical application of the biopsychosocial model is one that is free from the constraints of the biomedical model in which the practitioner uses the hierarchy of natural systems in patient treatment (Engel, 1980). From the information provided, a natural system-practitioner can be mindful of the course of the individual's health, thus, the care of the individual may be influenced by the prior psychological interpersonal levels of experience and behavior, thus, speaking to the psychological aspect of the athlete (Engel, 1980).

While the social construct found in the model may help examine how athletes interact with coaches, fellow players, sports fans, and psychologists, for the purpose of this study, the focus will be on the biological and psychological aspects of the model. The biological component to this model is focused primarily on the relationship between psychological processes and underlying physiological events. With regards to concussions, an athlete who resisted acknowledging that he or she suffered a concussion, especially when there was a brief window of unconsciousness, gives the psychologist a glimpse into his or her psychological state and conflicts.

Concussions

A concussion is commonly known as the "silent epidemic" due to its covert consequences it places on the athlete (Goldstein, 1990). Concussions have been referred to as "the quiet career killer" in the NFL because many players that have been forced into retirement (Anderson, 1992) and in 2015, Stamm et al., noted that there is an association with football and cognitive impairments later in life because of repeated head impacts. Concussions can be defined in two aspects: traumatic alteration in mental status that may or may not involve loss of consciousness (Aubry et al. 2002). Concussions can result indirectly when a force comes into contact with the body and the kinetic energy is transmitted to the head as in hitting the ground hard. The force can be great enough to move into the head region causing bruising to the brain (Aubry et al. 2002). In 2017b, according to McCrory et al., the definition of sports-related concussion has not deviated from its original definition and McCrory and his colleagues would argue that a more valid definition would help in the identification of concussions. Decades later, Broglio et al. (2017) recognized there is still a problem when it comes to operationally defining concussion.

Currently, a "one size fits all" model characterizes guidelines for how coaches and athletes respond to sports-related concussions, regardless of the number of concussions or nature of the injury (Collins et al., 2014). However, this "one size fits all" approach does not address the highly diverse nature of this injury which may result in cognitive changes (Collins et al., 2014). In addition, Clarsen and Bahr (2014) noted that no single definition can account for all needs and there needs to be a movement away from standard methodology approach and a movement towards individualized surveillance of the athlete. Three years later Broglio et al., (2017) have mentioned the same dilemma in which no clear-cut definition can be agreed upon for concussion. A multifaceted approach that considers individual differences and the number of reported head injury is needed to help sport and health professionals develop a greater understanding of risk factors and cognitive deficits associated with sports-related concussions (Collins et al., 2014). This multifaceted approach will influence outcomes along with more comprehensive assessments of concussions, identification of concussions, and risk factors (Collins et al., 2014).

From 1997 to 2007, mTBI incident rates are three times as prevalent from a decade ago in adolescents aged 14-19, rising from 7,000 in 1997 to nearly 23,000 in 2007 (Kimbler et al., 2011). Youth participation in sports has been on the rise over the past decades and paralleling this trend is an increase mTBI occurrence which creates a bigger problem (Kimbler et al., 2011). Sports-related concussions in this population often appear less mild compared to college and professional athletes (Guskiewicz et al., 2011), which leads to refusal of treatment and premature return-to-play and possibility of second impact syndrome (Kimbler et al., 2011). While standardized measures are in place for adults, they are neither suitable nor specific for the developing adolescent brain (Kimbler et al., 2011). Many clinicians who serve children and adolescents find themselves using principles and guidelines designed for adults and therefore do not consider the developing brain which needs more time to recover than an adult brain (Caine et al., 2014; Karlin, 2011; Meehan et al., 2011).

Concussion management among college athletes has received more attention than in the past decade as a result of the NFL lawsuit titled In Re: National Football League Players' Concussion Injury Litigation of 2012 (Phillips, 2015). State and federal legislation has mandated coaches, parents, and athletes to attend concussion meetings prior to the start of practice and the season so they are better informed on concussions and the risks associated with them which has been driven by Congress creating the SAFE PLAY ACT which mandates education and protocols surrounding concussions (Phillips, 2015).

While great strides in concussion management has occurred such as policies and protocols, there is still much room for improvement, particularly in non-NCAA sports where minimal attention is given (Baugh et al., 2015). Baugh and Kroshus (2016) noted once more that there are limitations and discrepancies with current concussion management protocols among colleges and universities. First, concussion education varies from one college to the next which makes it challenging to determine its efficacy among athletes (Baugh and Kroshus, 2016). Second, concussion training is usually carried out by one individual which can limit generalization across settings because it is delivered from the lens of one single professional (Baugh and Kroshus, 2016). Utilizing an interdisciplinary team approach where clinicians, athletic trainers, and other mental health professionals delivered the training and content would provide more knowledge to the athletes through multiple lens (Baugh and Kroshus, 2016).

As far as generalization is concerned, even with great strides on concussion education and protocols, it is still unclear if compliance across all Division I, II, or III universities are the same because all academic institutions have not released their concussion management plans (Buckley et al., 2017). Psychologists should be taking more of a lead on concussion research due to their contribution in psychological assessments and their knowledge base of psychological, cognitive, and psychosocial effects of concussions (Guay et al., 2016). Major findings in the aforementioned studies suggests more time for recovery for adolescents, individualized multifaceted approach to concussions in youth, and proper education and recognition for all involved with that youth (Collins et al., 2014; Karlin, 2011; Kimbler et al., 2011; LeClerc et al., 2001; Meehan et al., 2011).

Concussion Classification (Grading)

Sports-related concussions that are mild in nature and have no loss of consciousness are very prevalent, accounting for 75% of brain injuries in sports (LeClerc et al., 2001). According to the American Academy of Neurology, in 1997 guidelines were originated by the Colorado Medical Society (Kelly et al., 1991 and Silver et al., 2005). The 2013 guidelines moved away from concussion grading and highlighted the importance of performing comprehensive neurological assessment prior to the athlete's return-to-play (Giza et al., 2013). Even with the guidelines, there is still much confusion and ambiguity about which concussion grading system is more effective (Mullaly and

Hall, 2017). Table 2 depicts the most commonly used grading systems currently used with three different orientations to concussion grading by the American Academy of Neurology, Robert Cantu, and the Kelly et al of which all three describe each Grade differently (Mullaly and Hall, 2017). There is no clear definition that spans all three models, thus creating consistent inconsistencies which is the main reason for moving away from these grading systems and moving to a universal system (Giza et al., 2013).

	American Academy of Neurology	Cantu	Kelly et al
Grade 1	Confusion, symptoms last < 15 minutes, no loss of consciousness	Post-traumatic amnesia < 30 minutes, no loss of consciousness (mild)	Confusion, no loss of consciousness
Grade2	Symptoms last > 15 minutes, no loss of consciousness	Loss of consciousness < 5 minutes or amnesia lasting 30 minutes-24 hours (moderate)	Confusion, post-traumatic amnesia, no loss of consciousness
Grade 3	Loss of consciousness IIIa-unconsciousness for seconds IIIb-unconsciousness for minutes	Loss of consciousness or > 5 minutes or amnesia > 24 hours (severe)	Loss of consciousness

Source: (Mullaly and Hall, 2017).

While there is a universal commitment to the seriousness that concussions pose, there is not the same consensus of regarding grading (LeClerc et al., 2001). The expertise of practitioners, psychologists, and researchers appears to be the basis for the grading system, yet there is no empirically based evidence to support this system (LeClerc et al., 2001). Currently, there are approximately 19 different concussion models with variations of the grading system and all have their own “return-to-play” protocols (Lovell et al., 2012). The common frame of reference for assessing and grading the severity by most is the loss of consciousness and post-traumatic amnesia (LeClerc et al., 2001). With respect to prognosis, these parameters can be utilized in cases of severe head injuries; however, no published study has done the same for sport-related concussions (LeClerc et al., 2001). Post-concussion signs and symptoms are often the main predictors in helping professionals diagnose concussions (LeClerc, et al., 2001). Medical practitioners along with other health professionals often rely on neuropsychological testing to provide objective measures (LeClerc et al., 2001). Collectively, major findings have moved in the direction of practitioners, coaches, and other health professionals to be intimately familiar with signs, symptoms, and recognition of concussions in athletes under their care, as well as neuropsychological testing in detection of the injury (LeClerc et al., 2001).

Mullaly and Hall (2017) have formulated a grading system below that can be universal in nature and utilized by all, thus avoiding confusion. McKee's 2012 report on chronic traumatic encephalopathy helped guide this grading system for Mullaly and Hall (2017) due to the nature of repetitive blows to the head and the widespread deposition of p-tau in the brain.

Grade 1	Head contusion/laceration with no alteration in mental status
Grade 2	Head trauma or flexion extension injury of the cervical spine with no alteration in mental status precipitating a transient headache with or without migrainous features
Grade 3	Head trauma or cervical flexion extension injury resulting in a change in mental status with anterograde amnesia of < 30 minutes or loss of consciousness of < 1 minute
Grade 4	Head trauma or cervical flexion extension injury resulting in a change in mental status with anterograde amnesia of > 30 minutes but < 24 hours or loss of consciousness of > 1 minute but < 5 minutes

Grade 5	Head trauma or cervical flexion extension injury resulting in a change in mental status with anterograde amnesia > 24 hours; or loss of consciousness of > 5 minutes; skull fracture; cerebral contusion; increased intracranial pressure; intracranial pressure

Source: (Mullaly and Hall, 2017).

Despite the parameters, guidelines, and symptom recognition, collectively, major findings conclude that concussions are unique by nature, distinguishing themselves from other forms of traumatic brain injuries (Noble and Hesdorffer, 2013). Typically, concussions pose a challenge for medical professionals as well as psychologists by displaying no identifiable structural neural injury using neuroimaging tools such as computerized tomography (CT) and low field magnetic resonance imaging (MRI) (Noble and Hesdorffer, 2013). Conversely, high field magnetic resonance imaging (MRI) coupled with diffusion tensor imaging (DTI) provide the intricate details of the microstructure of white matter fibers, though not very cost effective, aid in prognosis and diagnosis of a concussion (Noble and Hesdorffer, 2013). Despite neuroimaging efforts, concussions pose challenges due to their functional disturbance characteristics which do not appear on neuroimaging tools versus a pathological injury (Odle, 2017).

Common Signs and Symptoms

Signs observed	Signs reported by an athlete
• Appears to be dazed or stunned • Is confused about assignment • Forgets plays	• Headache • Nausea • Balance problems or dizziness • Double or fuzzy vision

• Is unsure of game, score, or opponent • Moves clumsily • Answers questions slowly • Loses consciousness (even temporarily) • Shows behaviors or personality change • Forgets events prior to hit (retrograde) • Forgets events after hit (anterograde)	• Sensitivity to light or noise • Felling sluggish • Feeling "foggy" • Change in sleep pattern • Concentration or memory problems

Source: Lovell (2012)

Concussion Assessment

The first line of defense in assessing concussions starts on the field with an initial assessment of airway, breathing, and circulation (ABCs) along with cervical spine stabilization (Halstead & Walter, 2010). According to the IOM (2014) and Halstead and Walter (2010), a sideline evaluation includes symptoms of an athlete, neurologic examination using an assessment tool, and level of cognition by trained professionals. An acute evaluation occurs after discounting a more severe head injury (Lovell et al., 2012). Loss of consciousness can be brief in nature and may be missed by other eye witnesses (Lovell et al., 2012). Loss of consciousness occurs is a rare occurrence and is found in approximately 10% of concussions (Lovell et al., 2012). Both Lovell et al., (2012) and Halstead and Walter (2010), collectively agree that loss of consciousness is a coma that is brief in nature where the athlete is unresponsive to external stimuli for a period; longer than 30 seconds could indicate a more significant intracranial injury.

Traditional medical procedures such as CT, MRI, and EEG are useful in diagnosing more serious medical conditions such as skull fractures and hematomas and contribute minimally to the identification and management of concussions (Lovell et al., 2012), (Halstead & Walter, 2010). Such tests can show normal findings or a false positive result of a concussed individual due to the metabolic nature of a concussion (Lovell et al., 2012).

Neurocognitive tests such as ImPACT measure cognitive insufficiencies by targeting neurocognitive abilities that have been affected because of a concussion by performing an initial baseline assessment prior to the inception of the season and comparing it to an athletes' concussed state to determine the discrepancy from the baseline (Schatz and Robertshaw, 2014). The authors Schatz and Robertshaw (2014) stated that without a baseline assessment prior to the start of the season, the healthcare professionals would have no prior knowledge of any background information prior to an athlete being concussed, so they would not be able to determine any discrepancies from their baseline scores.

In 2004, the Concussion in Sport Group (CISG) developed and implemented the Sport Concussion Assessment Tool, commonly known as the SCAT (Echemendia et al., 2017). In the subsequent years the SCAT was revisited and reviewed based on empirical literature and at the Berlin 2016 Consensus Conference on Concussion in Sport, it was determined that the SCAT5 was the most recent revision of this assessment tool (Echemendia et al., 2017). The SCAT5 consisted of five domains: (1) adult SCAT, (2) child SCAT, (3) sideline assessment, (4) video surveillance/observable signs of concussion, and (5) oculomotor assessment (Echemendia et al., 2017).

Concussion Management

Appropriate concussion management according to the ImPACT Team usually comprised of a team physician, athletic trainer, and coaches is crucial and starts with a baseline test before and after an injury (Lovell et al., 2012). Neurocognitive baseline testing can objectively determine an athlete's injury from a concussion by comparing the results to the baseline and again to the post-injury tests, thus tracking the data and avoiding premature return to play by the team's physician (Lovell et al., 2012). Neurocognitive testing can prevent cumulative effects of concussions; however, these tests by themselves are not enough for the identification of concussions and their relation to cognitive impairments (IOM, 2014). The ImPACT neurocognitive assessment tool is the most validated battery that is widely used to guide improvements to concussion management protocols by neuropsychologists, physicians, and athletic trainers (Lovell, 2015).

Donaldson et al., (2014) noted the consensus of concussion management and guidelines are noted above and are recommended by the majority of health care professionals. A 2011 report of physicians' review showed concussion management and guidelines being used 36% of the time based on liberal improvements (Donaldson et al., 2014). Donaldson et al., (2014) recommended moving toward an implementation model which incorporates specific strategies and other evidence-based practices into the diagnosis and management of concussions such as competency, organizational, and leadership aspects. Mullaly and Hall (2017) noted similar concerns and gathered information from various sources to construct their own grading system consisting of head and brain injury. Donaldson et al. (2014) recognized that emergency and family physicians, athletic trainers, coaches, and parents do not follow, know, or use the prescribed guidelines.

Gender Differences and Concussions

There has been insufficient data regarding sports concussions in youth populations along with other demographic information such as sex, age, race, and ethnicity (IOM, 2014). However, with sports-related concussions in the spotlight, female athletes are gaining attention. Over the past decade, the number of women athletes has been on the rise and in 2008, 41% of high school athletes were females (Frommer et al., 2011). The rapid succession of female athletes over the years has brought about increased rates of injuries as well, thus, female athletes have surpassed their male counterparts for sports-related concussions (Frommer et al., 2011; Lincoln et al., 2011). With this increase in female athletes, return-to-play guidelines still remain universal even though females have a poorer outcome after a traumatic brain injury than their male counterparts before, during, and after the concussion (Andre-Morin et al., 2017; Broshek et al., 2005; Brown et al., 2015; Covassin et al., 2017; McCrory et al., 2017).

Zuckerman et al. (2015) examined sports-related concussion in NCAA athletes from 2009-2010 to 2013-2014 and noted sex differences in 4 out of 5 comparable sports. When examining women's sports such as soccer (female, 12.5% vs. male, 3.6%) lacrosse (female, 9.1% vs. male, 5.9%), and softball (female 9.4% vs. male baseball 0.0%), it was noted that females exhibited a higher rate of concussions than the males of the same sports (Zuckerman et al., 2015). Closer examination of this phenomenon points to body mass between male athletes versus female athletes where females' head and neck displacement are much smaller than their male counterparts, thus, making them more susceptible to concussions due to weaker muscles (Chamard et al., 2013; Zuckerman et al., 2015). Female athletes are susceptible to displaying more symptoms in the acute phase and require a longer recovery period than their male counterparts (Covassin et al., 2012; Preiss-Farzanegan et al., 2009). Chamard and colleagues (2013) noted that there were chronic alterations in concussed female athletes via magnetic resonance spectroscopy in the hippocampus and primary motor cortex regions of the brain as well as microstructural alterations in white matter and corpus callosum. In addition, female concussed athletes showed brain abnormalities in the white matter and cellular metabolism months post-injury despite an absence of symptoms (Chamard et al., 2013).

Another area of concern that separates male athletes from female athletes is body mass. Differences among the two sexes are most notable in impact force, neck strength, and neurocognitive performance, especially in the sport of soccer where females are heading the ball (Gutierrez et al., 2014). "Headers" in soccer or subconcussive impacts are the "silent assassins" lurking in the background because these subconcussive impacts are not clinically identifiable through testing batteries and they maybe correlated with long-term degeneration of cerebral tissue (Gutierrez et al., 2014). Gutierrez et al., (2014), found that neck strength and the muscles associated with it decreased the magnitude of impact and was an important variable in the minimization during “headers” whereas athletes with weaker necks could not diminish the impact.

Tierney et al., (2008) noted that female athletes while experiencing higher head accelerations, displayed weaker neck strength when compared to their male counterparts. Brogio et al., (2012) and Viano et al., (2007) collectively corroborated the aforementioned studies that increased neck strength and muscles lowered decrease the magnitude of impact, thus lessoning the full effects of subconcussive impacts.

Concussed male athlete’s response versus a female athlete’s response to concussions has not been widely examined according to Frommer et al., (2011) and is subjective at best. Major findings in these studies point out that male and female athletes’ response to a concussion presented with different types of symptoms (Frommer et al., 2011) along with deviating from the “one size fits all” approach and moving to a multifaceted approach (Broshek et al., 2005). Wasserman et al., (2016) reported a difference in symptoms from sports-related concussions between sexes of the same sport. For example, female athletes displayed more neurobehavioral symptoms, headaches, excessive drowsiness, nausea, and vomiting when compared to male athletes (Brown et al., 2015; Wasserman et al., 2016). Also, female athletes reported neurobehavioral and somatic symptoms while male athletes reported cognitive symptoms (Frommer et al., 2011).

Research suggests that female athletes have higher risk for concussions than male athletes and need longer recovery time (Covassin et al., 2012). In addition, there is minimal research to suggest differences in gender on symptoms, neurocognitive testing and memory, and postural stability (Covassin et al., 2012). The neuropsychological consequences have been studied in male athletes, while the consequences to female athletes are relatively unknown (Chamard et al., 2013).

Collectively, all the aforementioned studies indicate that there are unique challenges faced by female athletes when compared to their male counterparts in comparable sports. To date, most of the attention and research have been focused on male athletes, specifically football (Wasserman et al., 2016). As a result, female athletes have not been examined until recently, although there is research demonstrating that females are 1.4 times more likely to experience a sports-related concussion when compared to their male counterparts (Andre-Morin et al., 2017).

2016 5th International Consensus Conference on Concussion in Sport- Berlin, Germany

For over 35 years, there has been debate on the consensus of the definition of a concussion. Despite a heightened awareness surrounding concussions, a clear-cut definition has still posed controversy for many (IOM, 2014). Since the 2012, the International Consensus on Sport Concussion held in Zurich, the definition of concussion by Aubrey (2002) and McCrory et al., (2013) has become the traditional definition adopted by most healthcare professionals. In October 2016, the International Consensus on Sport Concussion (McCrory et al., 2017a) held in Berlin has modified the previous definition and has put forth the following definition of sport-related concussion:

Sport related concussion is a traumatic brain injury induced by biomechanical forces. Several common features that may be utilized in clinically defining the nature of a concussive head injury include:

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

The clinical signs and symptoms cannot be explained by drug, alcohol, or medication use, other injuries (such as cervical injuries, peripheral vestibular dysfunction, etc) or other comorbidities (eg, psychological factors or coexisting medical conditions (McCrory et al., 2017a, p. 2).

The purpose of this conference was to make available improvements to health and safety recommendations for athletes who have been injured by sport-related concussions by reviewing prior International Consensus Conferences and making appropriate revisions and re-evaluating past protocols while making recommendations for newer protocols (McCrory et al., 2017a).

Improvements on how concussions are viewed were a hallmark of the Berlin 2016 Conference in that a multidimensional approach should be utilized in testing (McCrory et al., 2017a). The SCAT5 is the most well-established tool for sideline assessment but should be used in conjunction with other tools such as checklists and sideline video reviews (Echemendia et al., 2017; McCrory et al., 2017a). Lastly, consideration on how special populations were examined, regardless of athletic ability level should be approached in the same manner, while special considerations should be made to children and adolescents due to the lack of empirical data and will be examined at future consensus meetings (Echemendia et al., 2017; McCrory et al., 2017a).

Although the 2016 Berlin conference made gains in being more specific in their definition of sport-related concussion, they fell short in other areas leaving many issues unresolved such as: (1) Should TBIs be in the same classification as a concussion? (2) Use of instrumented helmets to report data and whether the information reported is accurate and precise and (3) The final determination regarding a sport-related concussion diagnosis has no definitive guidelines but rather left for clinical judgment (Echemendia et al., 2017a; McCrory et al., 2017).

Neuropsychological Consequences of Concussions

Neuropsychological testing on athletes has been occurring since the 1980s from the pencil-and-paper method to computerized testing and has tested for the same domains of cognition: memory, cognitive processing speed, and reaction time (Harmon et al., 2013), (Iverson and Schatz, 2015). These testing procedures should not be used alone, but rather in conjunction with concussion management protocols and other experts in the field (Harmon et al., 2013).

Second-Impact Syndrome

Second Impact Syndrome is a controversial term due to the rare nature surrounding this type of injury. There have been only a few confirmed cases of second impact syndrome, thus lending itself to more questions than answers (Foris and Donnally, 2017). This syndrome came to light in 1973 and was officially named in 1984 (Gordon, 2017). Although the term has been around for decades, some critics of the second impact challenge its existence because of its rarity (McKee et al., 2014). At the present, Stovitz et al., (2017) recognize its definition is poor and is still not universally accepted despite decades of its existence. According to Wetjen et al., (2010) there are no statistics on the incidence or prevalence of this syndrome, which is described as a second head impact while suffering from post-concussion syndrome from a prior head injury sustained within the previous two weeks. The results of the second head injury are cerebral swelling, brain herniation, and death (Bey, 2009). With the aforementioned results of a second head injury, the literature pertaining to second impact syndrome is inconsistent starting with a vague definition as well as mortality rates ranging from 50% to 100%, thus adding to the confusion (Stovitz et al., 2017).

Weinstein et al. (2013) examined a case study where a 17-year-old football player received a helmet-to-helmet blow on a punt return. Despite exhibiting symptoms, the adolescent athlete continued to play the rest of the game but continued to complain about headaches and dizziness (Weinstein et al., 2013). After seeing his primary care physician four days later, the athlete was cleared by his physician after an examination and returned to contact play on day 5 where he become unresponsive and had seizures on the field of play (Weinstein et al., 2013). Upon further examination, the athlete received a non-contrast computerized tomography scan that revealed thin bilateral subdural hematomas for which he received pharmacological interventions (Weinstein et al., 2013). The athlete was discharged 98 days later and 3 years later continued to display cognitive deficits, thus highlighting the severity of second impact syndrome and the ambiguity from athlete to athlete as well sport to sport (Weinstein et al., 2013). Similar findings were reported by Fekete, pathologist in 1968 about a 16-year-old Canadian hockey player who received second impact four days after his initial impact, resulting in cerebral edema (Gordon, 2017). The major findings in these case studies looked at the premature return-to-play protocol prior to being medical cleared for reentry back into the game. Thus, education in this specific area is warranted to all healthcare professionals such as psychologists and those who are in direct contact with athletes.

Cumulative Effects

In 2015, Meier et al. examined cerebral blood flow following a sports-related concussion in 44 Division I college football athletes via an MRI scanner which was the first study of this kind. Meier et al., (2015) concluded that 17 concussed football athletes showed evidence of reduced cerebral flow following a sports-related concussion and during the recovery period when compared to the 27 non-concussed football athletes, thus adding an objective biomarker for sports-related concussions. Cumulative effect of concussions is an area of study is not without its controversies and critics. The correlation between athletes' self-reported history of concussions and their current neurocognitive condition is a question that has left many healthcare professionals such as psychologists and others puzzled (Collie, 2006). Brooks et al. (2013) noted that the literature on cumulative effects of concussions in adolescents was limited, mixed, and uncertain. Graham et al. (2014) reported the clinical literature on cumulative effects of concussions is limited by its weak methodology. On the other hand, Graham (2014) noted that most of studies that the Institute of Medicine committee reviewed showed that short-term effects of multiple concussions yielded diminished cognitive capacity in memory and processing speed indices.

A 2016 research report by LaFevor et al. noted that while an athlete who has been concussed is likely to make a full recovery, there are groups of athletes who have had multiple concussions which could lead to impairments in neurocognitive functioning. While mixed reviews surround this topic, athletes who have sustained two or more concussions showed signs of deficits in verbal memory and reaction time when compared to the non-concussed athlete (LaFevor, et al., 2016).

Most, if not all studies on repeated concussion have focused on professional and adult male athletes with one head injury and it is difficult to identify and accrue a sufficient number of athletes with three or more concussions (Graham et al. 2014). Halstead and Walter (2010) noted that there is a cumulative effect of concussions on the developing brain, but the long-term consequences are unknown. Schatz et al. (2011) recommends that this level of uncertainty of cumulative effects should raise the level of vigilance to those who work with adolescent athletes. Regardless of the number of concussions, there remains a level of uncertainty after four decades of exploring cumulative and lingering effects of sports-related concussions. Nevertheless, repeated concussions appear to be characterized by deficits in cognitive functioning, longer recovery time, and symptomatic presentation differences (Brown et al., 2015; Iverson et al., 2012; Yumul and McKinlay, 2016).

However, Covassin et al. (2017) noted that females are at greater risk for concussions when compared to their male counterparts. Females displayed greater neurocognitive deficits in the acute and subacute phases of concussions along with more symptoms and a longer recovery period than their male counterparts due to body mass, neck strength, and physiological genetic makeup (Covassin et al., 2017). In addition to body chemistry, Chamard et al. (2016) examined structures of the brain in eight non-concussed and 10 concussed female athletes, specifically the corpus callosum. Magnetic resonance imaging detected abnormalities in the brain structure of the anterior part of the corpus callosum in the 10 female concussed athletes, thus affecting the prefrontal and premotor areas of the brain (Chamard et al., 2016). Overall, most of studies reported concussed female athletes demonstrated slower or diminished times with respect to reaction time and visual memory scores (Broshek et al. 2005); (Colvin et al. 2009); (Covassin et al. 2012).

Conclusion

Chapter 2 provides an outline of research in the areas of biopsychosocial model and its clinical applications in sports, sports-related concussions, specifically signs, symptoms, management, treatment, and recommendations, neuropsychological consequences of concussions, neurocognitive testing, and ImPACT overview. Research on sports-related concussions has confirmed there is insufficient data regarding sports concussions in the youth populations along with other demographic information such as sex and age. While neurological tests by themselves do not provide adequate identification or diagnosis of concussions, further study is needed of the relationship between test scores and cognitive impairment (IOM, 2014). Neuropsychological and neurophysiological consequences on concussion research has shown that after receiving multiple blows to the head, there are alterations in white brain matter (IOM, 2014). Research on the psychological conditions surrounding concussions are characterized by a heightened level of anxiety which include ruminative thoughts, hypervigilance, being overwhelmed, sadness, and hopelessness (Collins et al. 2014). Brooks et al. (2013) noted that the literature on cumulative effects of concussions in adolescents was limited, mixed, and questionable. Authors Collie (2006) and Brooks et al. (2013) both concluded that adolescent athletes with one, two, or more concussions show no neurocognitive deficits using the ImPACT battery. ImPACT (Immediate Post-Concussion Assessment and Cognitive Testing) is the first, most-widely used, and most scientifically validated computerized concussion evaluation system and is widely utilized in various settings such as high schools, colleges and universities, and at the professional level (Lovell et al., 2012). While neurocognitive testing batteries, signs and symptoms, and recommendations have been examined, the cumulative effects of concussions in adolescents have conflicting evidence (Brooks et al., 2013). There are significant gaps in the literature such as research of cumulative effects of concussions on adolescent athletes (Brooks et al., 2013). Future research is needed in the area of gender differences and the effects of concussions in males versus females (Brooks et al., 2013). In addition, future research on sports-related concussions in other sports outside of football need to be conducted (Halstead and Walter, 2010).

The main purpose of this study is to close or eliminate the gaps in the literature by exploring the relationship between number of sports-related concussions and its cumulative effects on adolescent athletes via type of sport, age, and sex differences. The gap remains in the area examining similarities as well as differences between concussed male athletes versus concussed female athletes and the cumulative effects associated with repetitive subconcussive and concussive impacts in female athletes. By examining concussed female athletes in the same manner as concussed male athletes, the contribution to psychology can benefit through further exploration of cumulative effects of multiple concussions and its effects on cognition. Change begins with focusing on number of concussions an athlete has sustained, the range in sports where concussions are prevalent, and concussions among different sexes.

Chapter 3 discusses the study's design and framework. In addition, further elaboration of the neurocognitive battery (ImPACT) and its features, interpretation, reliability, and validity is discussed as well as its subtests. Research questions, hypothesis, and statistical analysis are also further discussed.

Chapter 3: Research Methodology

Introduction

This quantitative non-experimental research study is proposed to describe archival data using the Biopsychosocial Model to examine concussions. The available archival data examines correlates of repeated concussions sustained during collegiate athletics from a Division III university in the northeast United States. The proposed study's goal is to contribute information that may be used to inform policies about how and when athletes return to play following one or multiple concussions. College coaches, administrators, athletes, and health providers can use this information along with existing approaches in concussion management.

The purpose of this quantitative analysis of secondary data is to identify whether there is a correlation between assessment scores as predicted by number of concussions, demographic variables (age and sex), type of sport, and/or all of the aforementioned variables in college-aged athletes. The dependent variable (DV) is the change in the assessment score and the independent variables (IV) are number of concussions, type of sport, raw age, and sex.

Within this chapter, further discussion of the research design and sample is described as well as how the data will be collected. The data are not in public domain and permission to use the data is required through the university's research department. Acknowledgement of the data source is provided. However, anonymity of all participants and the university is maintained in the Acknowledgement section of this study.

Research Design and Rationale

The research design is a retrospective using secondary data. The quantitative data was obtained from a Division III university in the northeast United States which used the ImPACT (Immediate Post-Concussion Assessment and Cognitive Testing) computerized concussion management tool. Subjects included in this study were 484 college aged athletes ranging from 18 to 24 years of age during the 2013-2014 academic year. The demographic information related to each subject included age, sex, and education level. Variables within this study were used in a multiple regression analysis to determine the relationship between the number of concussions and type of sport, and gender over the course of a single academic year of 2013-2014.

Communication went through the Head Athletic Trainer to request data with administrative oversight from the Vice President for Research and Chief Research Officer and clinical oversight from the university psychologist and team physician. Contact was made formally through a “lead letter” to the Vice President for Research and Chief Research Officer to ensure fidelity and integrity of the data to be collected. A brief narrative along with this researcher’s prospectus about the study’s methods and purpose was presented to the Vice President for Research and Chief Research Officer.

Research Questions and Hypothesis

Repetitive head impacts over the course of a single football season without clinically-evident concussion showed changes in white matter associated with recurring helmet impacts and continued 6 months following no contact (Bazarian et. al., 2014).

Research Question 1

Do post-neurocognitive assessment scores, based on the ImPACT, deviate from initial baseline scores after multiple concussions?

Research Hypothesis 1

H_1:1 Multiple concussions scores significantly deviate from initial baseline scores.

H_0:1 Multiple concussions do not significantly deviate from initial baseline scores.

Research Question 2

Do post-ImPACT computerized neurocognitive assessment scores deviate from initial baseline scores in certain sports (baseball. basketball, football, ice hockey, lacrosse, rugby, soccer, volleyball, wrestling)?

Research Hypothesis 2

H_1:2 Scores of certain sports significantly deviate from initial baseline scores.

H_0:2 Scores of certain sports do not significantly deviate scores from initial baseline scores.

Research Question 3

Do post-ImPACT computerized neurocognitive assessment scores deviate from initial baseline scores in certain sexes?

Research Hypothesis 3

H_1:3 Certain sexes significantly deviate scores from initial baseline scores.

H_0:3 Certain sexes do not significantly deviate scores from initial baseline scores.

Research Question 4

Do post-ImPACT computerized neurocognitive assessment scores deviate from initial baseline scores in specific ages?

Research Hypothesis 4

H_1:4 Specific ages significantly deviates scores from initial baseline scores.

H_0:4 Specific ages do not significantly deviate scores from initial baseline scores.

Research Question 5

Do post-ImPACT computerized neurocognitive assessment scores deviate from initial baseline scores due to all of the above variables?

Research Hypothesis 5

H_1:5 All of the above variables significantly deviate scores from initial baseline scores.

H_0:5 All of the above variables do not significantly deviate scores from initial baseline scores.

Data Collection of Main Study

The Division III northeastern university supported this researcher by agreeing to provide redacted data following IRB approval that contained no identifying markers per Health Insurance Portability and Accountability Act of 1996 (HIPAA) guidelines which covers data privacy and security provisions for safeguarding medical and health information of all individuals (Retrieved from https://www.hhs.gov/hipaa). The "Safe Harbor" method was used which involves the removal of 18 types of identifiers to ensure no actual knowledge or residual information can be used to potentially identify an individual.

Throughout this study, all data were stored in accordance with the Health Insurance Portability and Accountability Act of 1996 (HIPAA). While the study was in progress, all information was stored away from all unauthorized individuals and locked in a file cabinet in a locked room when not in use. Upon completion of this study, all secondary data provided by the Division III university was destroyed; the Athletic Department at the university maintains the original data set. For the purposes of this study, all participants (N = 484) were analyzed from the school academic years 2013-2014.

Data Setting

The Division III university from which the data was derived has a population of approximately 2,000 students, with approximately 400 intercollegiate athletes. The university administered the ImPACT test one time at baseline and subsequent times post-concussion with the entire population of collegiate athletes for the 2013-2014 academic year. I used all available secondary data for the study. The deidentified data from the university provided the documentation from each athlete's initial baseline test and the results from their post-concussion test. In addition, the data showed how many concussions the athlete had over the course of a year and which aspects of cognitive functioning (memory, reaction time, etc.) were affected. The concussion test results which are confidentially saved within the ImPACT software were compared to the athlete's initial baseline test at the beginning of the academic year to determine changes because of a head injury. The data could then be used to dictate clinical management of the injury. To date, none the university's data on concussions based on ImPACT test scores have been analyzed to discern patterns of cognitive deficits among genders.

The ImPACT scores served as the outcome (dependent variable). The method in which to evaluate a head injury was based on ImPACT (Immediate Post-Concussion Assessment and Cognitive Testing) which is the first, most-widely used, and most scientifically validated computerized concussion evaluation system.

The ImPACT data has been collected by the university to baseline all athletes during the summer prior to the inception of the new school-sports calendar year. The data are gathered by the athletic trainers under the tutelage of the team physician once they have undergone an initial ImPACT training. The baseline test can be administered by a physician, nurse, psychologist, athletic trainer, athletic director, or coach before the start of a school-sports calendar year. However, licensed practitioners are the only individuals who can administer and interpret an ImPACT post-injury test (ImPACT Applications Inc., 2018). Results of the post-injury test are compared to scores from the baseline test baseline scores to assist the practitioner in the next steps of when the athlete can return-to-play.

Reliability of Instrumentation

As with all psychological and neuropsychological tests, ImPACT is subject to some threats to reliability, i.e. the reproducibility of scores over time and across examiners or situations. Since ImPACT is administered via a computer with standard instructions, as long as the examiner adheres to the setup instructions (e.g. quiet room, free from distractions) and has a reliable internet connection, many of the sources of unreliability are eliminated (i.e. an examiner varying instructions or inappropriately administering an item). With issues such as maturation, if an examiner is comparing the individual to the normative data, then of course that is not a concern since the normative data are by age. However, when an examiner is comparing an individual to his or her baseline performance, the examiner should be using a baseline test that is within 24 months of the date of retesting as there has been studies showing the test reliable over this period of time. The concept of regression is accounted for in the Reliable Change Index (RCI) calculations which are the primary indicators for differential performance (ImPACT Applications Inc., 2018.)

The analysis of the secondary data will identify whether or not there is a correlation between assessment scores as predicted by number of concussions, demographic variables (age and sex), type of sport, and/or all of the variables in the college athletes. ImPACT (Immediate Post-Concussion Assessment and Cognitive Testing) which is used by many entities around the world is one of the first scientifically validated computerized concussion evaluation system (ImPACT Applications, Inc., 2018). This assessment tool was developed by Drs. Mark Lovell and Joseph Maroon in the early 1990's to provide valuable information to assist qualified practitioners in making decisions when an athlete should return to play. Authors Lovell and Maroon reported the internal consistency reliability of the ImPACT was determined by

Cronbach's alpha; reliability of the psychometric test (ImPACT Applications, Inc., 2018). ImPACT is used in many settings such as high schools, colleges, professional sports teams, and many healthcare practices (ImPACT Applications, Inc., 2018).

The baseline test takes approximately 45-minutes to complete. The authors of the ImPACT assessment tool recommend a baseline test be taken every two years (ImPACT Applications, Inc., 2018). When a concussion is suspected, a 25-minute post-injury test is administered by a licensed healthcare provider and test results are compared to baseline scores (ImPACT Applications, Inc., 2018). The post-injury test has become the gold standard tool utilized in comprehensive clinical management of concussions for athletes from ages 12 to 59 years (ImPACT Applications, Inc., 2018).

Test Features

The ImPACT test covers an array of features and is only one tool used to assist psychologists and many other healthcare professionals in making return-to-play decisions for athletes. The ImPACT test measures multiple aspects of cognitive functioning such as attention span, working memory, sustained and selective attention time, response variability, non-verbal problem solving, and reaction time. There are numerous amounts of tests within the software to minimize practice effects (ImPACT Applications, Inc., 2018). ImPACT assessment tool has features such as the ability to measure player symptoms, measure verbal and visual memory, processing speed, and reaction time (measured to a $1/100^{th}$ of a second), assist clinicians, psychologists, athletic trainers, and other healthcare providers in making return-to-play decisions, provide reliable baseline test information, produce a comprehensive report of test results in a PDF format for others to view, automatically stores data from repeat testing, and testing is administered online for individuals and/or groups (ImPACT Applications, Inc., 2018).

Test Overview

The ImPACT test consists of five sections (ImPACT Applications, Inc., 2018). Section 1: Demographic information and health history questionnaire, Section 2: Current symptoms and conditions, Section 3: Neuropsychological Tests (baseline testing and post-injury testing - Module 1: Word Memory, Module 2: Design Memory, Module 3: X's and O's, Module 4: Symbol Matching, Module 5: Color Match, and Module 6: Three Letter Memory), Section 4: Injury description, and Section 5: ImPACT test scores

In 2013, Schatz and Ferris examined one-month test-retest reliability among 25 undergraduate athletes with no history of concussion who completed 2 baseline assessments 4 weeks apart using the ImPACT assessment battery. Schatz used the same dependent variables as the previous study and noted improvement only in Visual Motor Speeds scores, while the other composite scores remained stable over a one-month timeframe (Schatz and Ferris, 2013). In addition, practice effects were nonexistent on memory performance or reaction time within re-administration of the ImPACT assessment battery (Schatz and Ferris, 2013).

Bruce et al. (2014) investigated a 1-year test-retest reliability of the ImPACT assessment battery in 305 random professional hockey players in which Verbal Memory, Visual Memory, Reaction Time, and Visual Motor were examined. Players were tested by the team neuropsychologist in groups no larger than five and in the language of their choice (Bruce et al., 2014). All players met certain criteria such as no concussion between time of baseline and retest, no history of learning disability/ADHD, and had a baseline and were retested (Bruce et al., 2014). The investigation yielded mixed results between Verbal and Visual Memory composite scores and possibly a Type 2 error, thus possibly misclassifying an athlete and returning them back to play prematurely (Bruce et al., 2014).

Nakayama et al. (2014) studied the test-retest reliability of the ImPACT assessment battery in 85 athletes (51 male, 34 female) between baseline, 45 days, and 50 days. Once again, the dependent variables were visual memory, verbal memory, reaction time, and visual motor speed (Nakayama et al., 2014). Results yielded reliable scores at 45 and 50 days after the initial baseline assessment (Nakayama et al., 2014).

Validity

Validity of the ImPACT assessment tool has been questioned by other healthcare professionals because there are no official guidelines in place for computer-based neurocognitive testing (Allen and Gfeller, 2011). The data was collected through the athletic department at the Division III northeastern university. When examining validity in this quantitative non-experimental research study, most threats to validity apply more to experimental designs versus the available archival data which was used in this study.

When examining external validity in this research study, the sample of the study was taken into consideration such as the size of the sample. Threats to external validity in this study will be if the results cannot be generalized to other settings, other people and over time. This examiner did not collect the data firsthand, but rather it was collected by university personnel in the athletic department. Within internal validity, determining if there is a causal relationship between the independent and dependent variable are taken into consideration. Threats to internal validity include, but are not limited to, this examiner's conclusion between the independent variable and the dependent variable, specifically, the causal relationship between the two. Also, perhaps a deviation in the dependent variable could potentially be contributed to other factors. In addition, this examiner cannot account for the specific events which occur between the first ImPACT test assessment and subsequent tests.

Data Analysis

The analysis is a retrospective study using secondary data. This quantitative one-time measure focuses on analysis of secondary data obtained from a Division III university in the northeast United States which used the ImPACT (Immediate Post-Concussion Assessment and Cognitive Testing) computerized concussion management tool. Variables within this study will be used in a multiple regression analysis to determine the relationship between the number of concussions and type of sport, and gender over the course of a single academic year of 2013-2014.

The analyses were performed using Intellectus software (Intellectus statatistics, 2017, Retrieved from http://analyze.intellectusstatistics.com.) Descriptive statistics examined kurtosis, mean, percentage, sample minimum, sample maximum, sample size, skewness, standard deviation, and standard error of the mean. Outliers were observed for age, number of concussions, baseline, post injury 1, 2, 3, 4, and difference in baseline scores to post injury 1, 2, 3, and 4. I tested the hypothesis using a repeated measures Analysis of Variance (ANOVA) on the same subjects. This was done for baseline, post injury 1, and post injury 2 for Research Hypothesis 1. Within the repeated measures ANOVA, degrees of freedom, F ratio, normality, outliers, partial Eta squared, p-value, residuals, sphericity, and type I errors were examined.

For Research Hypothesis 2, 3, and 4, a one within one between ANOVA (independent variable is nominal; dependent variables are scale) will be used to examine the differences among repeated measures dependent variables and between groups of the independent variable. Research Hypothesis 2 will examine for baseline and post injury 1 by current sport. Research Hypothesis 3 will examine for baseline and post injury 1 by gender. Research Hypothesis 4 will examine for baseline and post injury 1 by age. Within the one-within one-between ANOVA, degrees of freedom, F ratio, normality, outlier(s), partial Eta squared, p-value, residuals, sphericity, and type I errors will be examined.

For Research Hypothesis 5, a multiple linear regression will be used to explain the relationship between the dependent variable (baseline score) and the independent variables (sport, gender, age, post injury score). A 95% confidence interval will be used while examining degrees of freedom, dummy-code, F ratio, homoscedasticity, multicollinearity, normality, outlier(s), p-value, residuals, R-Squared statistic, standardized beta, studentized residuals, t-test statistic, unstandardized beta, standard error, and variance inflation factors. Post hoc testing using a Bonferroni *p* value correction was conducted. Bonferroni corrections are a conservative way to analyze the means of pairwise comparisons and are used to control Type I error rates (Rafter, Abell, & Brasolton, 2002).

Ethical Considerations

The preceding data which was from a Division III University in the northeast was collected with fidelity and integrity under the auspices of the Vice President for Research and Chief Research Officer. All identifiable personal information was redacted by the head athletic trainer prior to this researcher obtaining the data to ensure the confidentiality of all participants and the university. A Certificate of Completion from the National Institute of Health (NIH) Office of Extramural Research on "Protecting Human Research Participants" was completed on September 20, 2015 (Certification # 1863486).

In the event of a breach of information, the HIPAA Breach Notification Rule is enacted. This rule requires covered entities to notify individuals who have been affected by the breach no later than 60 days of the discovery of the breach. All precautions were followed set forth by the Health and Human Services Department of the government. This includes administrative, physical, and technical safeguards for covered entities to ensure the confidentiality and integrity of all protected health information of all individuals involved. To ensure confidentiality of all athletes, baseline scores and post-injury test scores were collected and stored on a HIPAA compliant server.

Summary

Chapter 3 provides the methods for examining the way concussions are examined and approached. The purpose of this study is to inspect whether there is a potential correlation between testing scores after multiple concussions and initial baseline score. All data were redacted of all identifiable markers and obtained with fidelity and integrity in accordance with HIPAA laws. Ethical considerations, validity, and reliability were attended to in Chapter 3.

Chapter 4 concentrates on a proposal overview and the results of the analysis in greater detail.

Chapter 4: Results

Introduction

The topic of concussions among the athletic community has sparked much research and has risen to the forefront of issues in the athletic community (Valasek, 2012). As recent as November 2018, the National Hockey League (NHL) settled a four year, $18.9 million dollar lawsuit with more than 100 former NHL players who sued the NHL over brain injuries they had suffered over the course of their careers (Kilgore, 2018.) Incidence rates of 300,000 concussions have been reported by the Centers for Disease Control and Prevention (CDC) annually, though there is limited information on concussions sustained by athletes attending universities other than Division 1A universities. Additionally, few studies have gone beyond the mere incidence of concussions in order to examine reports of neurocognitiive outcomes following repeat concussions. In order to provide more information regarding neurocognitive outcomes following repeat concussions, the purpose of this quantitative analysis of secondary data was to identify whether there is a correlation between assessment scores as predicted by number of concussions, demographic variables (age and sex), type of sport, and/or all of the aforementioned variables in college-aged athletes.

This chapter details the results of the data analysis, beginning with a summary of the data collection procedures. Then, this chapter details descriptive statistics in order to describe the sample. Finally, this chapter presents the results of hypothesis testing.

Data Collection

As noted in Chapter 3, the Division III northeastern university supported this researcher by agreeing to provide redacted data following IRB approval that contained no identifying markers per Health Insurance Portability and Accountability Act of 1996 (HIPAA) guidelines which covers data privacy and security provisions for safeguarding medical and health information of all individuals (Retrieved from https://www.hhs.gov/hipaa**).** The *Safe Harbor* method was used which involves the removal of 18 types of identifiers to ensure no actual knowledge or residual information can be used to potentially identify an individual. Therefore, data collection has remained consistent with the description along with the following research questions and hypothesis reported in Chapter 3.

Research Question 1

Do post-neurocognitive assessment scores, based on the ImPACT, deviate from initial baseline scores after multiple concussions?

$H_0$1: Multiple concussions do not significantly deviate from initial baseline scores.

H_a1: Multiple concussions scores significantly deviate from initial baseline scores.

Research Question 2

Do post-ImPACT computerized neurocognitive assessment scores deviate from initial baseline scores in certain sports (baseball. basketball, football, ice hockey, lacrosse, rugby, soccer, volleyball, wrestling)?

$H_0$2: Scores of certain sports do not significantly deviate scores from initial baseline scores.

H_a2: Scores of certain sports significantly deviate from initial baseline scores.

Research Question 3

Do post-ImPACT computerized neurocognitive assessment scores deviate from initial baseline scores in certain sexes?

H_03: Certain sexes do not significantly deviate scores from initial baseline scores.

H_a3: Certain sexes significantly deviate scores from initial baseline scores.

Research Question 4

Do post-ImPACT computerized neurocognitive assessment scores deviate from initial baseline scores in specific ages?

H_04: Specific ages do not significantly deviate scores from initial baseline scores.

H_a4: Specific ages significantly deviates scores from initial baseline scores.

Research Question 5

Do post-ImPACT computerized neurocognitive assessment scores deviate from initial baseline scores due to all of the above variables?

H_05: All of the above variables do not significantly deviate scores from initial baseline scores.

H_a5: All of the above variables significantly deviate scores from initial baseline scores.

Results

Descriptive Statistics

Most students in the sample were male (*n* = 31, 63%). The sports played by students in the sample varied, but the largest proportion of students played rugby (*n* = 18, 37%). Frequencies and percentages are presented in Table 1.

Table 1
Frequency Table for Student Gender and Current Sport

Variable	*n*	%
Gender		
Female	18	36.73
Male	31	63.27
Missing	0	0.00
Current Sport		
Baseball	1	2.04
Basketball	2	4.08
Football	6	12.24
Ice Hockey	2	4.08
Lacrosse	1	2.04
Rugby	18	36.73
Soccer	5	10.20
Volleyball	4	8.16
Wrestling	7	14.29

Missing	3	6.12

Note. Due to rounding errors, percentages may not equal 100%.

On average, students were 19.47 years old (*SD* = 1.43). Students had an average of 1.10 concussions (*SD* = 1.39). For baseline ImPACT scores (Cognitive Efficiency Index) students scored an average of 0.32 (*SD* = 0.14). The Cognitive Efficiency Index measures the interaction between accuracy (percentage correct) and speed (reaction time) in seconds on the Symbol Match test. This score demonstrates an athlete's performance on how fast they completed symbol match (decreasing accuracy) or attempted to improve their accuracy by working deliberately slow (jeopardizing speed). The range of scores is from approximately zero to approximately .70 with a mean of .34. A higher score indicates that the athlete did well in both the speed and memory domains on the symbol match test. A low score (below .20) means that they performed poorly on both the speed and accuracy component. The athlete performed very poorly (reaction time component) if they received a negative score (ImPACT Applications Inc. (2018). In addition to the Cognitive Efficiency Index, there are five Composite Scores that are an integral part in determining the Cognitive Efficiency Index: Memory Composite (verbal), Memory Composite (visual), Visual Motor Speed Composite, Reaction Time Composite, and Impulse Control Composite. Scores that exceed the Reliable Change Index (RCI) have deviated significantly when compared to the baseline score for each of the five domains. For post injury 1 ImPACT scores, students had an average of 0.32 points (*SD* = 0.15). For post injury 2 ImPACT scores, students had an average of 0.40 points (*SD* = 0.13). The observations for post injury 3 had an average of 0.35 points (*SD* = 0.16). For post injury 4, students had an average of 0.45 points (*SD* = 0.13). Only one student had a score for post injury 5, who scored 0.63 points. Table 2 presents the summary statistics for these variables.

Table 2

Summary Statistics Table for Age, Number of Concussions and ImPACT scores

Variable	Minimum	Maximum	*M*	*SD*	*n*
Age	18.00	24.00	19.47	1.43	49
Number of Concussions	0.00	5.00	1.10	1.39	49
ImPACT Score:					
Baseline	0.03	0.59	0.32	0.14	49
PostInjury1	0.03	0.62	0.32	0.15	49
PostInjury2	0.10	0.64	0.40	0.13	33
Postinjury3	0.10	0.55	0.35	0.16	11
Postinjury4	0.32	0.57	0.45	0.13	3
Postinjury5	-	-	0.63	-	1

Note. '-' denotes the sample size is too small to calculate statistic.

Hypothesis Testing

Research Question 1. Research Question 1 and associated hypotheses state: Do post-neurocognitive assessment scores, based on the ImPACT, deviate from initial baseline scores after multiple concussions?

$H_0 1$: Multiple concussions do not significantly deviate from initial baseline scores.

$H_a 1$: Multiple concussions scores significantly deviate from initial baseline scores.

To address this research question, a repeated measure analysis of variance (ANOVA) was performed to see if significant differences exist among Baseline, PostInjury 1, and PostInjury 2. Prior to conducting the analysis, the assumptions of multivariate normality, homoscedasticity, and sphericity were assessed. Normality was evaluated using a Q-Q scatterplot (Field, 2009; Bates, Mächler, Bolker, & Walker, 2014; DeCarlo, 1997). Normality can be assumed if the datapoints generally conform to the diagonal line (Field, 2009). The assumption was met. The Q-Q scatterplot for normality is presented in Figure 1.

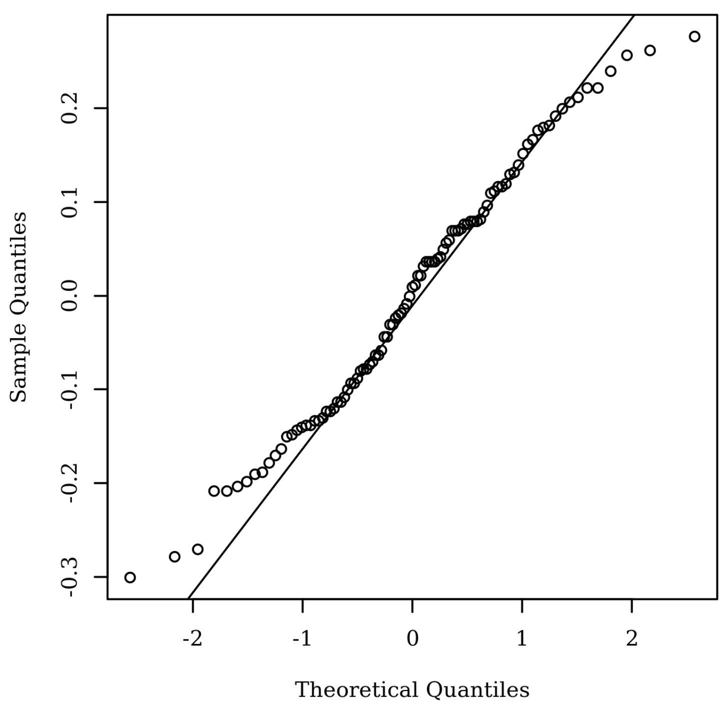

Figure 1. Q-Q scatterplot testing normality for Research Question 1.

Homoscedasticity was evaluated through a scatterplot of the residuals (Field, 2009; Bates et al., 2014; Osborne & Walters, 2002). If the data appears arrayed in columns, the assumption is met if the columns appear approximately the same height (Field, 2009). The assumption was met. Figure 2 presents a scatterplot of predicted values and model residuals. Mauchly's test was used to assess the assumption of sphericity (Field, 2009). The results were not significant, $p = .635$, indicating the sphericity assumption was met.

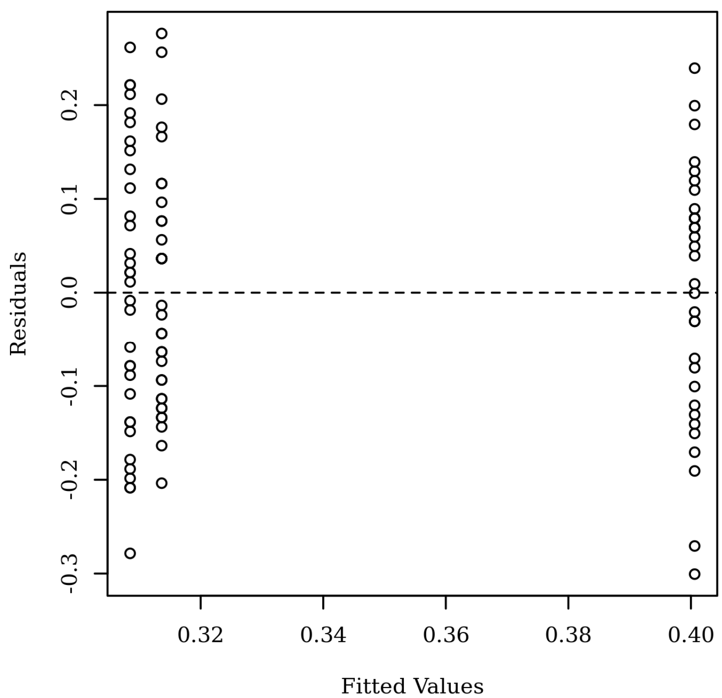

Figure 2. Residuals scatterplot testing homoscedasticity for Research Question 1.

The results of the ANOVA were significant, $F(2, 64) = 8.12$, $p < .001$, indicating there were significant differences among the values of baseline, post injury 1, and post injury 2 (See Table 3 for the full ANOVA table). Post hoc testing using a Bonferroni *p* value correction was conducted. Bonferroni corrections are a conservative way to analyze the means of pairwise comparisons and are used to control Type I error rates

(Rafter, Abell, & Brasolton, 2002). The mean value of baseline (*M* = 0.31, *SD* = 0.13) was significantly less than post injury 2 (*M* = 0.40, *SD* = 0.13). The mean value of post injury 1 (*M* = 0.31, *SD* = 0.15) was significantly less than post injury 2 (*M* = 0.40, *SD* = 0.13). No other significant differences were found. The means are presented in Table 4 and Figure 3. The null hypothesis was rejected.

Table 3

Repeated Measures ANOVA Table for Baseline, PostInjury1, and PostInjury2

Source	*df*	*SS*	*MS*	*F*	*p*	η_p^2
Within factor	2.00	0.18	0.09	8.12	< .001	0.20
Residuals	64.00	0.70	0.01			

Table 4

Means Table for Within-Subject Variables

Variable	*M*	*SD*
Baseline	0.31	0.13
PostInjury1	0.31	0.15
PostInjury2	0.40	0.13

Note. n = 33.

Research Question 2. Research Question 2 and associated hypotheses state: Do post-ImPACT computerized neurocognitive assessment scores deviate from initial baseline scores in certain sports (baseball. basketball, football, ice hockey, lacrosse, rugby, soccer, volleyball, wrestling)?

$H_0$2: Scores of certain sports do not significantly deviate scores from initial baseline scores.

H_a2: Scores of certain sports significantly deviate from initial baseline scores.

A mixed model ANOVA with one within-subjects factor and one between-subjects factor was conducted to answer this research question and determine whether significant differences exist in baseline and post injury 1 between the levels of current sport. Because of small group sizes, participants who played baseball, basketball, ice hockey, and lacrosse were grouped into one group (n = 18). The assumptions of multivariate normality and homoscedasticity were assessed. The assumption of the Q-Q scatterplot for normality are presented in Figure 2. Normality was assumed. The scatterplot of residuals is presented in Figure 3. There was slight evidence of heteroscedasticity, therefore, results may be treated with caution. However, the F test tends to be robust against violations of statistical assumptions (Stevens, 2009). Sphericity does not apply to this model, as there are only two repeated measurements being assessed (Field, 2013).

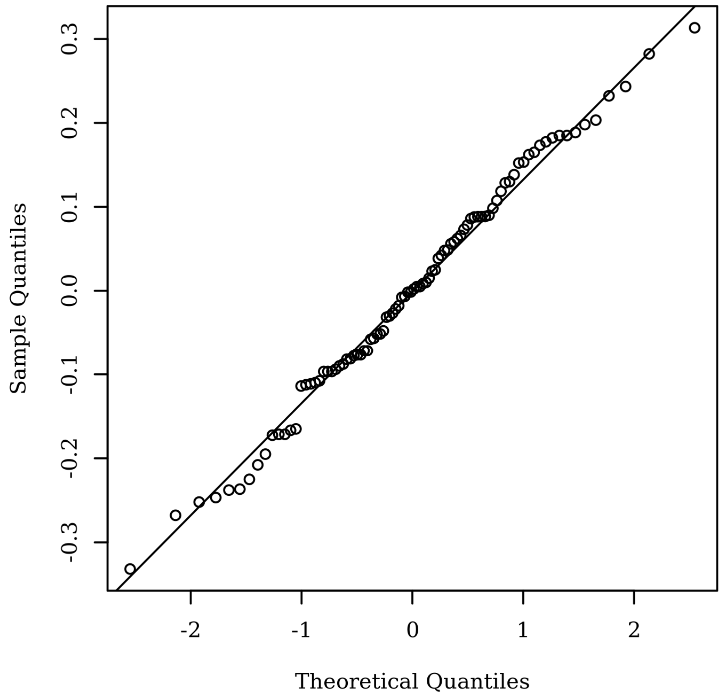

Figure 3. Q-Q scatterplot testing normality for Research Question 2.

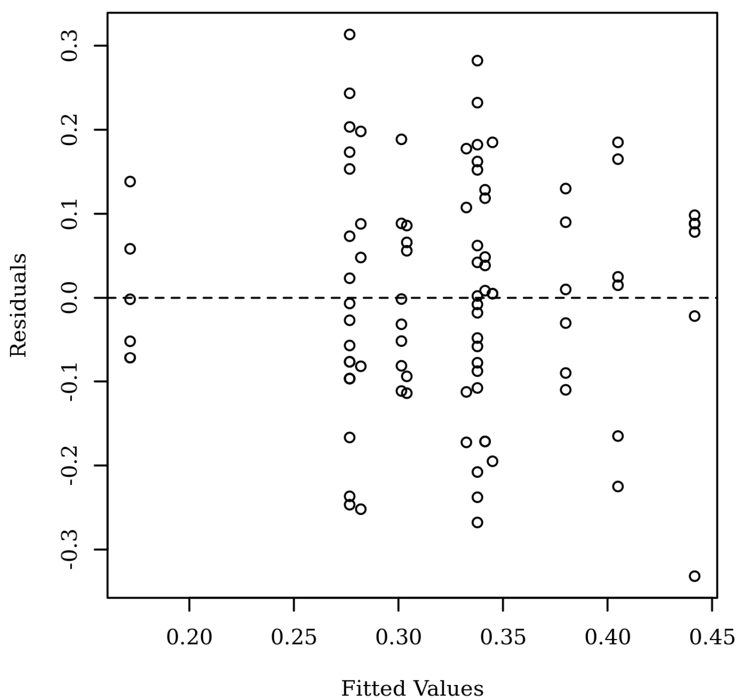

Figure 4. Residuals scatterplot testing homoscedasticity Research Question 2.

Results indicated that the main effect for current sport was not significant, $F(5, 40) = 1.01$, $p = .422$, indicating that the average impact score was similar amongst levels of current sport. The interaction effect between the within-subjects factor and current sport was significant $F(5, 40) = 3.58$, $p = .009$, indicating that there were significant differences among the values of baseline, post injury 1, and levels of current sport. As a result, the null hypothesis was rejected. Table 5 presents the ANOVA table.

Post hoc testing indicated that for students who played football, the mean value of baseline ($M = 0.38$, $SD = 0.10$) was significantly greater than post injury 1 ($M = 0.17$, $SD = 0.08$). There are a number of different reasons why a result would be in the opposite of the expected direction or a paradoxical result. Some reasons may include small sample size, which could amplify an anomalous measurement or an instrumentation effect that may have occurred specifically for football. For students who played rugby, the mean value of baseline ($M = 0.28$, $SD = 0.16$) was significantly less than post injury 1 ($M = 0.34$, $SD = 0.16$). There were no significant differences between baseline and post injury 1 for other sports. Table 6 presents means and standard deviations for each factor level combination and row and column totals.

Table 5

One-Within One-Between ANOVA Results for Current Sport

Source	*df*	*SS*	*MS*	*F*	*p*	η_p^2
Between-Subjects						
Current Sport	5	0.17	0.03	1.01	.422	0.11
Residuals	40	1.32	0.03			

Within-Subjects						
Within Factor	1	0.01	0.01	0.58	.452	0.01
Current Sport:Within Factor	5	0.17	0.03	3.58	.009	0.31
Residuals	40	0.39	0.01			

Table 6
Means and Standard Deviations for Factor Level Combinations of Current Sport

Current Sport	*n*	Baseline	PostInjury1	Row Average
Baseball, Basketball, Ice Hockey, or Lacrosse	6	0.40 (0.17)	0.44 (0.17)	0.42 (0.16)
Football	6	0.38 (0.10)	0.17 (0.08)	0.28 (0.14)
Rugby	18	0.28 (0.16)	0.34 (0.16)	0.31 (0.16)
Soccer	5	0.30 (0.10)	0.28 (0.17)	0.29 (0.13)
Volleyball	4	0.34 (0.16)	0.33 (0.17)	0.34 (0.15)
Wrestling	7	0.30 (0.10)	0.34 (0.12)	0.32 (0.11)

Column Average	-	0.32 (0.14)	0.32 (0.16)	0.32 (0.15)

Note. Standard deviations in parentheses.

Research Question 3. Research Question 3 and associated hypotheses state: Do post-ImPACT computerized neurocognitive assessment scores deviate from initial baseline scores in certain sexes?

$H_0$3: Certain sexes do not significantly deviate scores from initial baseline scores.

H_a3: Certain sexes significantly deviate scores from initial baseline scores.

A mixed model ANOVA with one within-subjects factor and one between-subjects factor was conducted to answer Research Question 3 and determine whether significant differences exist in baseline and post injury 1 between genders. The Q-Q scatterplot for normality is presented in Figure 5. Normality was assumed. The scatterplot of the residuals is presented in Figure 6. Homoscedasticity was assumed. Sphericity does not apply to this model.

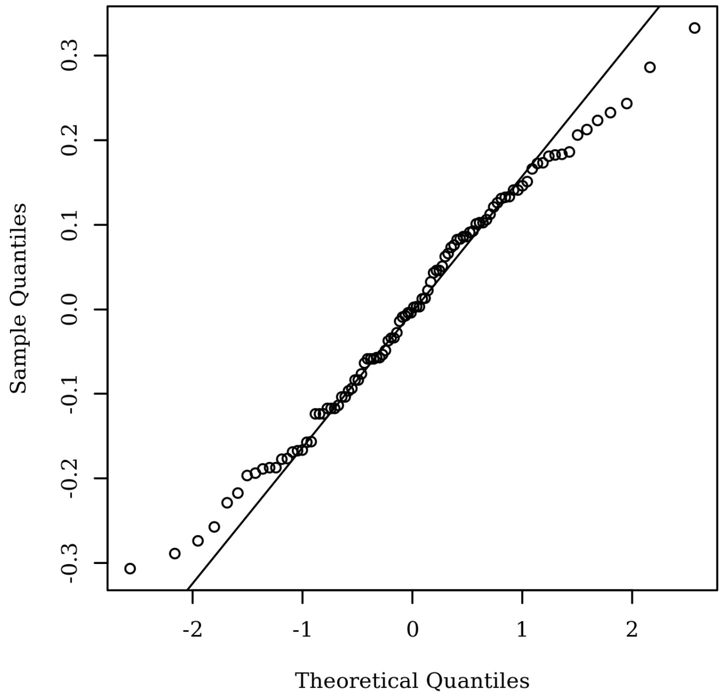

Figure 5. Q-Q scatterplot testing normality Research Question 3.

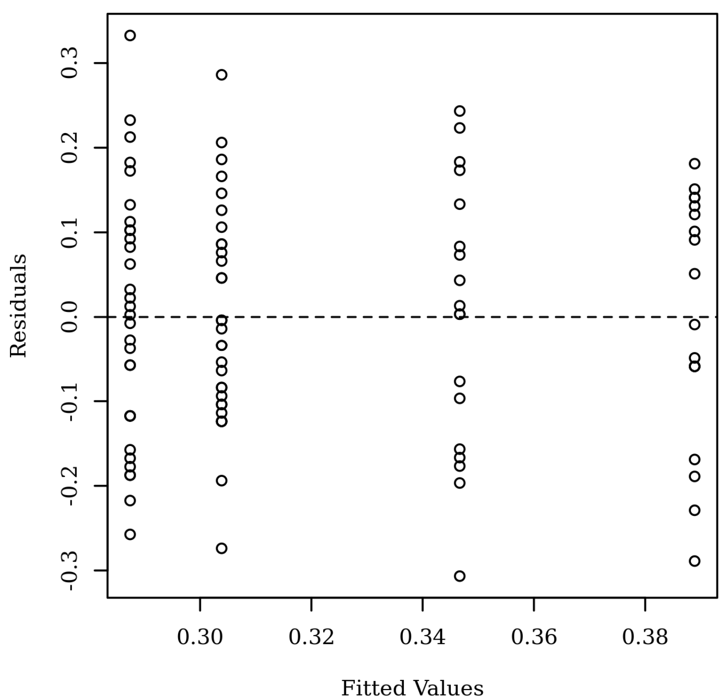

Figure 6. Residuals scatterplot testing homoscedasticity Research Question 3.

The main effect for gender was not significant, $F(1, 47) = 4.01$, $p = .051$, indicating the average ImPACT score were similar for both genders. The interaction effect between the within-subjects factor and gender was not significant, $F(1, 47) = 1.64$, $p = .207$, indicating that the change from baseline to post injury 1 scores did not differ based on gender. The null hypothesis could not be rejected. However, a strong trend towards significance was noted. The main effect of gender (which approached significance) would show that the scores for females (0.37) were higher than males (0.30). Table 7 presents the ANOVA results. Table 8 presents means and standard deviations for each factor level combination and row and column totals.

Table 7

One-Within One-Between ANOVA Results for Gender

Source	*df*	*SS*	*MS*	*F*	*p*	η_p^2
Between-Subjects						
Gender	1	0.12	0.12	4.01	.051	0.08
Residuals	47	1.39	0.03			
Within-Subjects						
Within Factor	1	0.00	0.00	0.32	.577	0.01
Gender:Within Factor	1	0.02	0.02	1.64	.207	0.03
Residuals	47	0.56	0.01			

Table 8

Means and Standard Deviations for Factor Level Combinations for Current Sport

Gender	*n*	Baseline	PostInjury1	Row Average
Female	18	0.35 (0.16)	0.39 (0.15)	0.37 (0.15)
Male	31	0.30 (0.13)	0.29 (0.15)	0.30 (0.14)
Column Average	-	0.32 (0.14)	0.32 (0.15)	0.32 (0.15)

Note. Standard deviations in parentheses.

Research Question 4. Research Question 4 and associated hypotheses state: Do post-ImPACT computerized neurocognitive assessment scores deviate from initial baseline scores in specific ages?

$H_0$4: Specific ages do not significantly deviate scores from initial baseline scores.

H_a4: Specific ages significantly deviates scores from initial baseline scores.

A mixed model ANOVA with one within-subjects factor and one between-subjects factor was used to answer the research question and to determine whether significant differences exist in Baseline and PostInjury1 between the levels of age as a categorical variable. The Q-Q scatterplot for normality are presented in Figure 7. The assumption of normality was met. The scatterplot of residuals is presented in Figure 8. The assumption of homoscedasticity was met. Sphericity does not apply for this model.

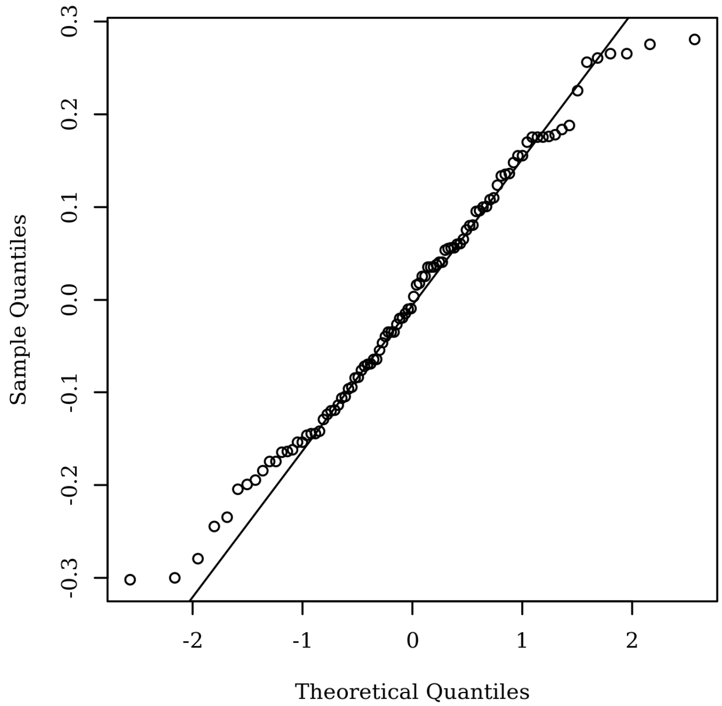

Figure 7. Q-Q scatterplot testing normality Research Question 4.

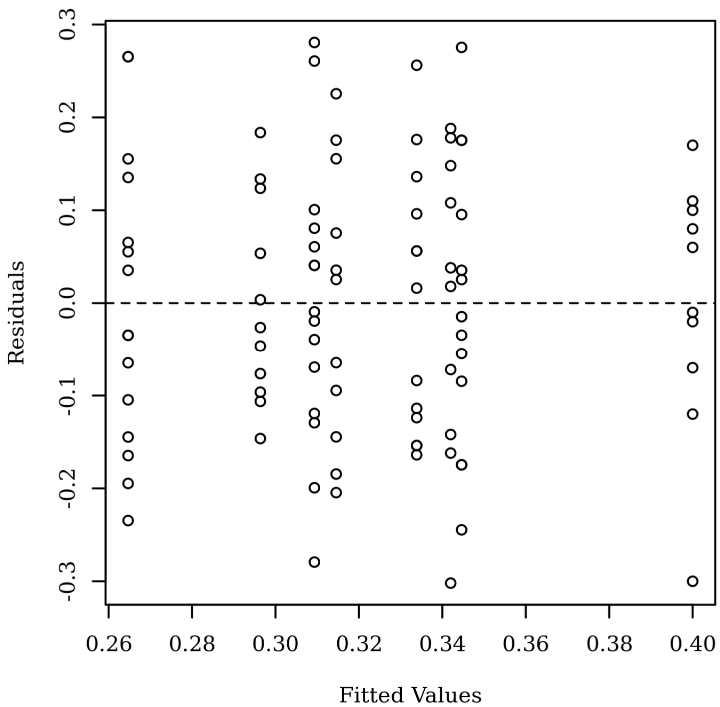

Figure 8. Residuals scatterplot testing homoscedasticity Research Question 4.

Results of the ANOVA indicated that there were no statistically significant differences in the average of ImPACT scores between ages. Additionally, the interaction effect between the within-subjects factor and age was not significant, $F(3, 45) = 0.92$, $p = .438$, indicating that there was no significant change in ImPACT scores from baseline to post injury 1 between ages. As a result, the null hypothesis was not rejected. Table 9 presents the ANOVA results. Table 10 presents means and standard deviations for each factor level combination and row and column totals.

Table 9

One-Within One-Between ANOVA Results for Age

Source	*df*	*SS*	*MS*	*F*	*p*	η_p^2
Between-Subjects						
Age	3	0.10	0.03	1.05	.380	0.07
Residuals	45	1.41	0.03			
Within-Subjects						
Within Factor	1	0.00	0.00	0.22	.642	0.00
Age:Within Factor	3	0.03	0.01	0.92	.438	0.06
Residuals	45	0.55	0.01			

Table 10

Means and Standard Deviations for Factor Level Combinations for Age

age	*n*	Baseline	PostInjury1	Row Average
18	15	0.31 (0.15)	0.26 (0.16)	0.29 (0.15)
19	13	0.33 (0.14)	0.34 (0.15)	0.34 (0.14)
20	11	0.30 (0.11)	0.31 (0.15)	0.31 (0.13)
21+	10	0.34 (0.17)	0.40 (0.14)	0.37 (0.15)
Column Average	-	0.32 (0.14)	0.32 (0.15)	0.32 (0.15)

Note. Standard deviations in parentheses.

Research Question 5. Research Question 5 and associated hypotheses state: Do post-ImPACT computerized neurocognitive assessment scores deviate from initial baseline scores due to all of the above variables?

$H_0$5: All of the above variables do not significantly deviate scores from initial baseline scores.

H_a5: All of the above variables significantly deviate scores from initial baseline scores.

A mixed model ANOVA with one within-subjects factor and three between-subjects factors was used to answer the research question and to determine whether significant differences exist in Baseline and PostInjury1 between the levels of Current Sport, Age, and Gender. This research question asks the same question as Research Questions 2-4, except placing all independent variables into the same ANOVA model. As multiple testing was involved, a Bonferroni correction was applied, which reduced the alpha (*p* level for significance) to $p = .013$ from $p = .05$. The Q-Q scatterplot for normality are presented in Figure 9. The assumption of normality was met. The scatterplot of residuals is presented in Figure 10. The assumption of homoscedasticity was met. Sphericity does not apply for this model.

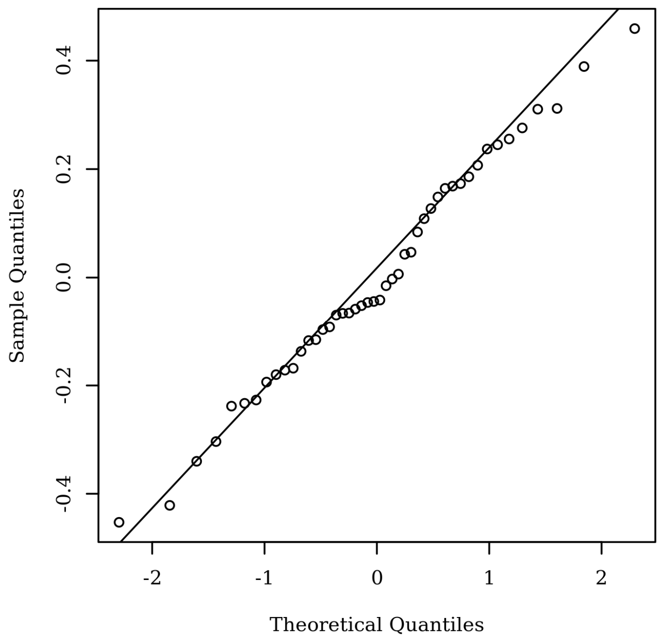

Figure 9. Q-Q scatterplot testing normality for Research Question 5.

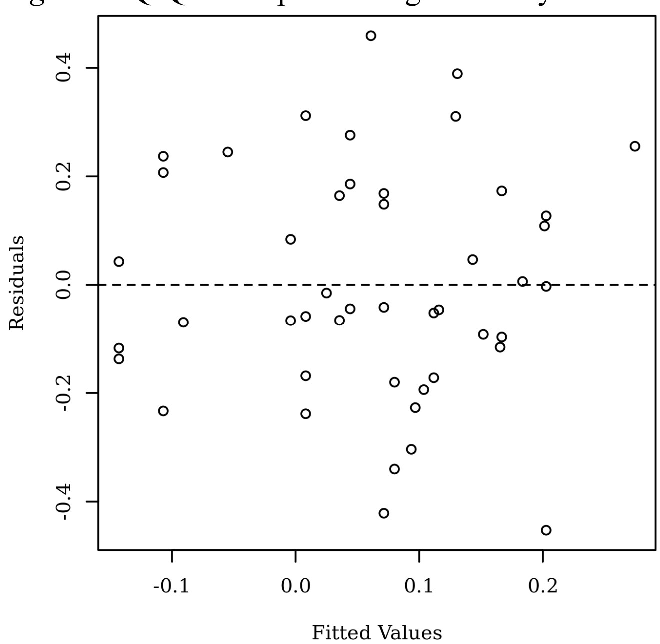

Figure 10. Residuals scatterplot testing homoscedasticity for Research Question 5.

Results of the ANOVA indicated that there were no significant differences at the Bonferroni-adjusted values in the average of ImPACT scores between genders, current sports, or ages. In addition, the interaction effect between the within-subjects factor and the independent variables were not significant at the Bonferroni-adjusted values. As a result, the null hypothesis was not rejected. However, in this model, significance was also found for the interaction effect involving current sport at the .05 level. The results for research question 2 showed that the sports that had significant differences between baseline and post-injury were football and rugby. This means that additional support was provided for the rejection of the null hypothesis for Research Question 2. Table 11 presents the ANOVA results.

Table 11

One-Within One-Between ANOVA Results

Source	*df*	*SS*	*MS*	*F*	*p*	η_p^2
Between-Subjects						
Current Sport	5	0.21	0.04	1.50	.214	0.17
Gender	1	0.12	0.12	4.25	.046	0.12
Age	3	0.15	0.05	1.76	.172	.128
Residuals	36	0.38	0.01			
Within-Subjects						
Within Factor	1	0.00	0.00	0.29	.593	0.01
Current Sport:Within Factor	5	0.15	0.03	2.88	.028	0.29
Gender:Within Factor	1	0.00	0.00	0.22	.644	0.01
Age:Within Factor	3	0.00	0.00	0.35	.792	0.03
Residuals	36	0.38	0.01			

Summary

Chapter 4 included an overview of this study by means of an introduction with the purpose of this study along with research questions and hypothesis, followed by data collection, results, and summary. Results of hypothesis testing indicated that the null hypothesis for Research Question 1 could be rejected; ImPACT scores after second injuries were higher than baseline scores and scores after first injuries. The null hypothesis for Research Question 2 could be rejected; for students who played football, baseline scores were significantly higher than scores after first injuries. For students who played rugby, baseline scores were significantly lower than scores after first injuries. There were no other significant differences in other sports. The null hypotheses for Research Questions 3-5 could not be rejected. $H_0$3: Certain sexes do not significantly deviate scores from initial baseline scores, $H_0$4: Specific ages do not significantly deviate scores from initial baseline scores, and $H_0$5: All of the above variables do not significantly deviate scores from initial baseline scores.

Chapter 5 includes reiterating the purpose and nature of the study and why it was conducted along with summarizing key findings. In addition, interpretation of findings, limitations of the study, recommendations, and implications. Along with implications, a description of the potential impact for positive social change will need to be addressed followed by the conclusion of the study.

Chapter 5: Summary, Recommendations, and Conclusions

Introduction

The purpose of this quantitative analysis was to determine whether or not there is a correlation between neurocognitive assessment scores as predicted by number of concussions, demographic variables (age and sex), type of sport, and/or all the aforementioned variables in college-aged athletes. Within this study, secondary archival data was analyzed to determine if there is a deviation in neurocognitive scores from the initial baseline line test to post-concussion test because of multiple concussions in college-aged athletes. Based on the analysis, results of hypothesis testing indicated that the null hypothesis for Research Question 1 could be rejected; ImPACT scores after second injuries were higher than baseline scores and scores after first injuries. The null hypothesis for Research Question 2 could be rejected; for students who played football, baseline scores were significantly higher than scores after first injuries. For students who played rugby, baseline scores were significantly lower than scores after first injuries. There were no other significant differences in other sports. The null hypotheses for Research Questions 3-5 could not be rejected.

Interpretations

Research Question 1

Do post-neurocognitive assessment scores, based on the ImPACT, deviate from initial baseline scores after multiple concussions?

$H_0 1$: Multiple concussions do not significantly deviate from initial baseline scores.

$H_a 1$: Multiple concussions scores significantly deviate from initial baseline scores.

Research question 1 explored the results of multiple concussions on the ImPACT scores. A repeated measures ANOVA was performed to test the differences between the different measurements, baseline and ImPACT scores post injury. Baseline versus up to two post-injuries scores were explored. The population sample was not sufficient enough to explore three or more post-injuries. Results showed that there is a difference in ImPACT scores at baseline and post-injuries, specifically, the ImPACT scores after sustaining a second post-injury were higher than both baseline and after one post-injury. The ImPACT score increased after two post-injuries compared to baseline and one post-injury. There are no noticeable differences after one post-injury and baseline. This result means that Impact scores only increase after a second injury, as no change was observed after one injury.

Research Question 2

Do post-ImPACT computerized neurocognitive assessment scores deviate from initial baseline scores in certain sports (baseball. basketball, football, ice hockey, lacrosse, rugby, soccer, volleyball, wrestling)?

$H_0$2: Scores of certain sports do not significantly deviate scores from initial baseline scores.

H_a2: Scores of certain sports significantly deviate from initial baseline scores.

Research question 2 examined change from baseline to post-injury while incorporating the type of sport each athlete played to see if the sport had an influence on the change of the ImPACT score. Specifically, the difference between baseline and the athlete's first post-injury. Results suggest that there is a significant effect of the type of sport played that influenced the ImPACT score's deviation from baseline to post-injury. The two variables explored are change from baseline to post injury and type of sport. Thus, the type of sport is influencing the change from baseline to post-injury. Post-hoc testing revealed a correlation between ImPACT tests scores and type of sport, specifically for athletes who played football, ImPACT scores are significantly decreasing from baseline to post-injury. Conversely, rugby athletes' ImPACT scores are significantly increasing from baseline to post-injury.

Considerations in other sports need to be further explored along with the same consistency from one sport to another. In the sport of football, Diffusion Tensor Imaging (DTI) has been used consistently while other sports have not benefitted from this technological approach (Maher et al., 2014). Other sports such as soccer could benefit from this technology to examine pathophysiology of concussions and the lasting effects of heading the ball (Maher et al., 2014). In addition, future research on sports-related concussions in other sports outside of football need to be conducted (Halstead and Walter, 2010).

Research Question 3

Do post-ImPACT computerized neurocognitive assessment scores deviate from initial baseline scores in certain sexes?

$H_0 3$: Certain sexes do not significantly deviate scores from initial baseline scores.

$H_a 3$: Certain sexes significantly deviate scores from initial baseline scores.

Research question 3 examined change from baseline to post-injury while incorporating the type of sex. Results yielded no significant differences. Therefore, since the interaction is not significant, the athlete's sex is not having an influence on the change in scores from baseline to post-injury, hence, female athletes suffer equal effects of concussions. The sex effect sample size may have been too low to low to detect statistically meaningful changes.

An area for future consideration is sex and gender, specifically outcomes as a result of concussions. According to Mollayeva et al., (2018), the current literature lacks information in this area, thus, making it difficult to generate policies and guidelines for best practice. As noted in Chapter 2, this has been an issue for years as literature is mostly focused on professional sports and there is minimal research to suggest differences in gender on symptoms, neurocognitive testing and memory, and postural stability (Covassin et al., 2012). The neuropsychological consequences have been studied in male athletes, while the consequences to female athletes are still in their infancy stage as compared to their male counterparts (Chamard et al., 2013). While this study had a limited sample size of female athletes to find a statistical difference, Sicard et al. (2018) noted long-term consequences in executive functioning in female athletes. Cognitive profiles in females differ from their male counterparts, whereas female alterations resulting from sports-related concussion can last into a chronic phase versus male athletes (Sicard et al., 2018).

Research Question 4

Do post-ImPACT computerized neurocognitive assessment scores deviate from initial baseline scores in specific ages?

$H_0$4: Specific ages do not significantly deviate scores from initial baseline scores.

*H*a4: Specific ages significantly deviates scores from initial baseline scores.

Research question 4 studied the change from baseline to post-injury while incorporating age of the athlete. Therefore, since the interaction is not significant, the athlete's age is not having an influence the change in scores from baseline to post-injury. The age effect sample size may have been too low to detect the relationship between age and the change in scores.

Research Question 5

Do post-ImPACT computerized neurocognitive assessment scores deviate from initial baseline scores due to all of the above variables?

$H_0$5: All of the above variables do not significantly deviate scores from initial baseline scores.

H_a5: All of the above variables significantly deviate scores from initial baseline scores.

Research question 5 explored the change from baseline to post-injury while incorporating all variables in the same analysis to assess differences while controlling certain variables. Results yielded no significant effects of type of sport, age, or gender.

Limitations

This study has several limitations. The first limitation is that individuals were administered only one neurocognitive battery at one time point to determine cognitive deficits, thus, there is only one baseline per athlete to be viewed. In an ideal situation, the administration of multiple batteries would be administered to provide more information to make a return-to-play decision for an athlete. Secondly, the sample size in this proposed study is smaller than preferred due to the size of the university's athletic department. Next, the ImPACT scores should be looked at from a longitudinal approach rather than one baseline test and subsequent tests after an injury. Also, preexisting archival data is being utilized for this non-experimental study. As a result, the author cannot control any of the variables in this non-experimental study. In addition, the following is a list of data sources that this researcher does not have access to: fMRIs, formal clinical interviews, familial histories, GPAs, academic performance, or discipline records. A longitudinal approach would provide a time series account of scores across a 4-year period that could be further examined. Also, this researcher does not have access to an athlete's file for a formal record review which would include academic grades in college, medical records, other types of evaluations if applicable, and prior high school records. Finally, this proposed study cannot control for other head injuries outside of the university. These limitations can provide useful information to athletic directors, health professionals, coaches, and parents.

Recommendations

This study proposes recommendations for future research into concussion protocol/management/policy. The return-to-play protocol is largely based on clinical judgement based upon each individual athlete due to the incomplete science that surrounds concussions (McCrory et al., 2017). Having a manualized standard protocol across the board will provide a level of consistency to all who are responsible for making decisions on when to return an athlete back onto the field. The governing bodies, coaches, and players of these sport institutions should have clear and concise guidelines on return-to-play protocols for athletes. In addition, according to Condiracci (2018), athletic trainers face challenges with regards to how each of them seeks consultation from psychologists/neuropsychologists on return-to-play and how they incorporate recommendations.

Specific considerations for college-aged athletes should be further examined on an individual level. Future guidelines for adolescents and young adults need to be clearly defined as far as an individualized treatment plan. Sports-related concussions impact various aspects of ones' life including academics, social and emotional well-being, sports, and family dynamics and these impacts differ from athlete to athlete (Halstead et al., 2018). The literature does not have a specific breakdown by age on how to manage concussion among young adults (McCrory et al., 2017). Signs and symptoms would have to be carefully explored to detect covert and overt differences if any, in signs and symptoms as well as recovery patterns (McCrory et al., 2017).

Further precautions for athletes need to be undertaken such as clinical interviews for athletes performed by clinical psychologists. These clinical interviews would focus on more than demographics and include background information such as developmental history, medical history, family history, school adjustment, and sports history. Within developmental history, age and level of difficulty in reaching milestones would be explored. Medical history would encompass hospitalizations, sugeries, extended illnesses, unusually high fevers, seizures, head injuries, broken bones, ear infections, visual problems, and somatic complaints. Family history would explore parent's history, learning difficulties in the family, alcohol/substance abuse, traumatic events, emotional issues such as psychiatric hospitalizations/counseling. School adjustment would focus on academic progress over the years, handling of transitions, relationships with teachers and peers, and behaviors. Sports history would entail details such as the age of the individuals when they first started playing sports, type of sports, injuries associated with each sport and the result of each injury, time away from the sport as a reuslt of the injury if any, under the supervision of a healthcare provider as a result of the injury, did the individual see a healthcare provider immediately after the injury, and frequency and duration of each injury.

A clinical interview performed by a clinical psychologist would provide parents, athletes, coaches, healthcare providers, educators, and administrators with a more thorough and indepth profile of each athlete. The psychologist would offer a narrative of each athlete through the lens that could not be provided by any other personnel. Upon completion of the clinical interview, if the psychologist felt more testing should be explored, then the psychologist would offer further testing recommendations before making an informed decision on this athlete. In addition, follow up evaluations performed by the psychologist should happen at the psychologist’s request on an as needed basis for each athlete. These recommendations would eliminate complacency among all college sports programs and take a more pro-active approach on how concussions are viewed. In addition, these parameters would focus on impact sports where high frequency contact and trauma to the head and body occur.

The definition of concussion is one that is still unclear and needs to be universal and operationally defined. Clarsen and Bahr (2014) noted that no single definition can account for all needs, and there needs to be a movement away from standard methodology approach and a movement towards individualized surveillance of the athlete. Three years later Broglio et al., (2017) mentioned the same dilemma in which no clear-cut definition can be agreed upon for concussion. A multifaceted approach that considers individual differences and the number of reported head injury is needed to help sport and health professionals develop a greater understanding of risk factors and cognitive deficits associated with sports-related concussions (Collins et al., 2014). This multifaceted approach will influence outcomes along with more comprehensive assessments of concussions, identification of concussions, and risk factors (Collins et al., 2014).

Implications for Positive Social Change

Despite mandated legislation, there are still gaps in knowledge about concussions. Although the gap is getting smaller, concussion education needs to increase in collegiate school systems as the risk for concussions is higher in physical education than professional sports (Campbell et al., 2018). As a result, improvements still need to be made in the delivery of services that meet the needs of all student-athletes while covering topics such as symptoms, recognition, cognitive and behavioral impairments, and management (Carroll-Alfano, 2017).

Concussion education at U.S. colleges is diverse with each university having its own policies and procedures about the depth and breath of concussion education. There needs to be a systematic approach to educating our communities (i.e. parents, coaches, school systems, health care professionals, students) that is universal in nature.

Concussion education can support the interdiciplinary community to view concussions on an individual basis, to better understand the risk factors associated with sports-related head trauma, and potentially can lead to greater identification and risk factors. Coaches, trainers, psychologists, and other health professionals can examine an athletes' baseline test scores on ImPACT test pre-concussion and then administer ImPACT test subsequent times post-concussion. This valuable information can help coaches, players, and health professionals on making more informed decisions in return-to-play protocols for athletes, thus preventing a premature return back to the sport. In addition, Skakoon (2018) noted that engineers at Stanford University are working on mouthguard technology that can measure forces from a sports impact that effect the brain with10 percent or less error. This would be a major step in the reduction of sports related concussions.

Implications for future change needs to be re-evaluated with a much more in-depth approach. It is not enough for athletes to receive a baseline test and then subsequent post-concussion tests for the reasons of sandbagging. Sandbagging or underperforming on baseline tests is a growing trend which can have neuropsychological consequences and cause premature return-to-play as dictated by a false-negative post-concussion test result (Raab and Peak, 2018). Raab and Peak (2018) noted that sandbagging is more prevelant and without detection than the previous literuature suggests on ImPACT testing.

The significance of concussion awareness is important to future athletes in the United States and around the world to promote positive social change. The importance of this national public health concern has reached Washington D.C. where President

Obama delivered opening remarks at the White House Healthy Kids & Safe Sports Concussion Summit in the East Room of the White House, May 29, 2014 (https://www.whitehouse.gov/blog/2014/05/29/president-obama-hosts-healthy-kids-and-safe-sports-concussion-summit). The significance of concussion awareness is important to future athletes in the United States and around the world by promoting better social change through improved behavior and health. Results from this dissertation suggest that there is a need to bring further attention to this national matter.

Conclusion

In conclusion, major findings in this study has provided evidence that post-neurocognitive assessment scores, based on the ImPACT, deviate from initial baseline scores after multiple concussions, indicating there were significant differences among the values of baseline, post injury 1, and post injury 2. Future research should be conducted with more participants to determine if there will be a significant value among age, gender, and sports. However, in this model, significance was also found for the interaction effect involving current sport. Therefore, it is assumed that these findings will be valuable for other researchers as they further examine the cumulative effects of sports-related concussions with larger samples and Division I and II sports programs.

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