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Reaction Time and Verbal Working Memory Differences in NCAA Concussed Female Athletes

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Abstract

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Dissertation Submitted in Partial Fulfillment

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Abstract

Empirical evidence suggests that female collegiate athletes participating in soccer are likely to suffer from TBI and subsequent concussion syndrome. Studies further indicate that TBI adversely affects the quality of life of athletes both on an academic level and social life. This study examined data with the intent to fill existing gaps in the current literature and focused on the experiences of NCAA female collegiate soccer athletes who have suffered TBI and neurocognitive deficit symptoms in verbal memory and reactional time. This quantitative research method relied on the theory of mind (ToM) as the theoretical basis to investigate research questions in investigating TBI's relationship and an individual's cognitive performance in verbal and reaction time. This quantitative study relied on a de-identified secondary dataset from the ImPACT injury database to evaluate baseline and post injury TBI evaluations, assessed injuries, and cognitive domains. The data were analyzed with descriptive statistics, paired sample *t* tests and independent sample *t* tests. There were significant differences in reaction time, but not statistically significant in verbal working memory. The implications of the study for positive change included the provision of insight into practical strategies for better management of the challenges associated with TBI to enable effect minimization of the cognitive deficits on the athlete's social and academic life. The study findings will therefore facilitate the development of strategies to enhance safety in sport.

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Dedication

I would like to dedicate my dissertation to my parents, Robert and Joann Delph, my brother, Brian Delph, my sister, and brother-in-law, Kristel and Eric Jefferson, and my nephews, Michael, Christopher, and David Jefferson. Thank you for all the love and support and especially for listening, encouraging, and motivating me to complete this journey.

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Chapter 1: Introduction to the Study

Introduction

Traumatic brain injuries (TBIs) are one of the most prevalent causes of death among athletes who participate in contact sports (Roebuck-Spencer & Cernich, 2014; Yang & Baugh, 2016; Zuckerman et al., 2012). Among those affected by TBIs are students who play soccer with cases of about 50,000 concussed soccer players reported every year (O'Kane et al., 2014). Of those who suffer TBIs about 30.5% succumb to the injuries (Roebuck-Spencer & Cernich, 2014). Those who survive and if not managed well, end up with adverse symptoms that negatively affect the quality of life (Zuckerman et al., 2012). Traumatic brain injuries also result in post concussion syndrome, which are characterized by prolonged symptoms (Daneshvar et al., 2011, Marshall et al., 2015).

The devastating symptoms of TBIs are the neurocognitive effects, which are characterized by damage to the nervous system leading to alteration of an individual's cognitive and behavioral conduct (Danna-Dos-Santos et al., 2018; Dymowski et al., 2015; Woods et al., 2015). The most affected neurocognitive functions are the executive functioning, learning and memory, attention, and processing speed (McInnes et al., 2017; Rabinowitz & Levin, 2014; Smucny et al., 2013). Neurocognitive symptoms adversely affect an individual in school, at home, and in their social relationships (Ransom et al., 2015). Student athletes with severe symptoms from a concussion suffer a significant decline in their academic performance and face challenges keeping up with their demanding athletic activities (Ransom et al., 2015; Yengo-Kahn et al., 2016).

The frequency of TBIs and the severity of the associated symptoms vary based on gender (Covassin et al., 2018). Female athletes have a greater risk of TBIs and face more severe consequences compared to male athletes (Covassin & Elbin, 2010; Dick, 2009). Despite the high number and the increased risk of concussion, cases of concussions remain underreported among female athletes (McDonald et al., 2016; O'Kane et al., 2014). Therefore, this study focused on neurocognitive symptoms that are associated with TBIs among female soccer athletes in collegiate sport.

Focusing on the female collegiate soccer athlete is important since there is an exponential increase in female athletes who participate in college soccer (Zuckerman et al., 2012). Given the evidence that shows that soccer predisposes athletes to high risk of TBIs, the increased number of female soccer players increases the female students who are at risk of concussion (Lipton et al., 2013; Zuckerman et al., 2012). By addressing the neurocognitive deficits among female collegiate soccer athletes, this study provided insights into the safety management of the cognitive challenges associated with TBIs and therefore could enable the affected female college soccer athletes to cope with the challenges of negative effects on their academic and sporting careers. This may contribute to reviews of collegiate concussion protocol programs and return to play policies to assess and reduce concussions in collegiate sports.

This chapter provided an introduction and synopsis of research to this quantitative study. The background information grounds the study and described what is currently known and what needs to be addressed about underrepresented female athletes and concussions. The problem statement described neurocognitive deficits experienced by concussed collegiate female soccer athletes as reaction time and verbal working memory declines. This chapter also describes the purpose, the nature of the study, research questions, assumptions, limitations, and significance of the importance of the research for positive change.

Background of the Study

Traumatic brain injury is damage to the brain caused by physical impact on the head (McInnes et al., 2017; Zuckerman et al., 2012). The injury results in detrimental effects on brain function, negatively affects quality of life for the concussed individual, and may cause death (Roebuck-Spencer & Cernich, 2014; Zuckerman et al., 2012). According to Roebuck-Spencer and Cernich (2014), TBI-related brain damage is characterized by the changes in the cognitive or behavioral function of an individual. Seriousness of TBIs depends on the degree of that injury and is usually defined by the time taken by the injured individual to regain consciousness (Roebuck-Spencer & Cernich, 2014).

Traumatic brain injuries are classified based on their severity, which is scored on the Glasgow Coma Scale: Assessment of Coma and Impaired Consciousness: A Practical Scale (GCS; Teasdale & Jennett, 1974). The scale provides the severity of the injury, which is based on how long a concussed individual takes to regain consciousness when they are stimulated (Roebuck-Spencer & Cernich, 2014). The severe cases of TBI are scored between 1 and 8 in GCS while the moderate cases score between 9 and 12. Those with a GCS score between 13 and 15 are classified as mild TBIs (Roebuck-Spencer & Cernich, 2014).

The most prevalent forms of TBIs are mild TBIs, which are also generally called concussions (McInnes et al., 2017). Unlike a moderate concussion, a mild brain injury can resolve after 3 months but may take longer especially among someone who suffers cognitive damage (Daneshvar et al., 2011; Hall et al., 2005). TBIs become serious especially when persistent post concussion syndrome occurs. Post concussion syndrome occurs when a concussed individual experiences the prolonged symptoms of a concussion (Daneshvar et al., 2011; Marshall et al., 2015). Researchers have suggested that about 15% of all individuals who sustained a TBI, may experience persistent post concussion syndrome (McInnes et al., 2017).

Among male and female athletes, TBIs are considered one of the leading causes of death and the cases are on the rise (Roebuck-Spencer & Cernich, 2014). The fact that about 3.8 million individuals per year experience TBIs in the United States suggests that the condition poses a serious challenge to the healthcare and the sporting sectors (Zuckerman et al., 2012). Taking appropriate steps to understand and address TBIs and associated effects is important in preventing the death due to TBI, which currently stands at 30.5% of the reported cases (Roebuck-Spencer & Cernich, 2014).

Traumatic brain injuries result in the alteration of the nervous system function, which adversely affects cognitive and behavioral conduct (Danna-Dos-Santos et al., 2018; Dymowski et al., 2015; Woods et al., 2015). Concussion results in adverse effects on various neurocognitive functions, such as the executive function, learning and memory, attention, and processing speed (McInnes et al., 2017). Focusing on the neurocognitive effects of TBI in this study was based on the resulting adverse consequences on the well-being of the affected individual (Rabinowitz & Levin, 2014). Reaction time refers to the duration that an individual takes to respond after perceiving a stimulant. Therefore, reaction time, in relation to the cognitive process, refers to the detection processing and response to a given stimulus (Jakobsen et al., 2011). The detection of a given stimulus involves the recruitment of neurocognitive functions that enable seeing, hearing, and feeling. Processing of the information enables one to understand the detected information (Jakobsen et al., 2011). Delayed reaction times due to TBIs result in adverse effects on the ability of individuals to react to visual and auditory stimulants (Danna-Dos-Santos et al., 2018). The delayed reaction times may adversely affect the adoption of appropriate behavior that is needed for survival and/or optimum athletic performance (Smucny et al., 2013).

Concussions also adversely affect verbal working memory (Wood & Wolgemuth, 2019). Verbal working memory is defined as a short-term memory mechanism that facilitates the retention of speech-related information for a short period and allows the verbalized information to be retrieved and used (Marvel & Desmond, 2016). The verbal working memory offer stored verbalized information such as numbers, words, and letters (van Dun & Mariën, 2016). Compared with individuals without a history of TBI, the prevalence of poor verbal working memory is high among those who have suffered TBIs (Green et al., 2018). Poor verbal working memory negatively affects students learning processes and has long-term effects on individual behavior and interaction with others (Green et al., 2018). Concussions also result in poor cognitive performance that can last for weeks (Covassin et al., 2010). Researchers have suggested that there is gender-based differences in cognitive performance outcomes following TBI between male and female athletes (Covassin & Elbin, 2010). The gender-based difference in the structural and chemical composition of the brain could be associated with the difference in response to TBI (Covassin & Elbin, 2010; Tierney et al., 2008). In relation to the parts of the brain concerned with memory and information processing, female brains differ from that of males in terms of neutrophil composition, which is high among females (Covassin & Elbin, 2010; Larsson et al., 2011).

There is consensus regarding the adverse effects of TBI in adolescents and young adults at school, home, and in their social relationships (Ransom et al., 2015). For students, TBIs present potential negative impacts on academic performance (Ransom et al., 2015). Concussions are associated with various symptoms that impede academic functioning. The post-TBI symptoms such as slow information processing, fatigue, headaches, and altered ability to concentrate are associated with limited academic performance (Ransom et al., 2015). Students with severe symptoms of TBIs may be forced to miss classes, which interferes with their learning and academic achievements (Ransom et al., 2015). Students who have suffered TBIs may also be unable to engage in challenging cognitive activities due to the possible worsening of the symptoms (Majerske et al., 2008).

Concussion also affects participation in sports (Mayers, 2008; Yengo-Kahn et al., 2016). For contact sports such as soccer, individuals who have suffered TBIs are normally required to avoid playing until they are cleared to return (Mayers, 2008). Although the action taken to avoid playing with symptoms of TBIs is important in ensuring the safety of the athletes, the affected individual may suffer psychological effects of feeling left out (Broshek et al., 2015). Upon returning to active sports, the affected individual may be forced to undergo intensive training to catch up with the rest of the team, which sometimes may involve physically and mentally demanding activities (Yengo-Kahn et al., 2016).

The assessment of TBI needs to focus on those who are most affected or at the risk of sustaining such injuries. Researchers have suggested that individuals who participate in athletics and contact sports are at a higher risk of sustaining TBIs (Yang & Baugh, 2016). About 44 million Americans actively participate in various organized sporting activities and these individuals are at risk of concussion (Yang & Baugh, 2016). Sahler and Greenwald (2012) highlighted the high prevalence of TBIs among young athletes. They described how TBIs could occur in contact sports and the need to focus on the athletes' wellbeing.

Lipton et al. (2013) noted that TBIs are high among students who participate in sporting activities such as soccer. According to O'Kane et al. (2014) about 50,000 soccer players experience TBI each year. The prevalence of TBIs among soccer players poses a serious threat since the sport is fast gaining prominence among high school students (Maher et al., 2014).

Sahler and Greenwald (2012) noted that TBIs constitute a challenge likely to pose increasing safety threats and concerns in college athletics. The researchers noted that the threat is set to increase as the number of students who are joining college sporting activities increase. Sahler and Greenwald acknowledged that one of the ways for effectively addressing TBIs and the associated effects is through adequate evaluation and management of the symptoms and emphasis on neurocognitive testing. The likelihood of adverse effects associated with TBIs increases with repeated TBIs (Covassin et al., 2010). Therefore, one of the effective ways to prevent the adverse consequences of TBI is by ensuring that there is an effective identification of the initial incidences of TBI to prevent exposure to a repeated concussion. Although efforts have been made towards the analysis of TBI among athlete students, there is a need to consider the fact that the symptoms may vary based on the gender of the athletes (Covassin et al., 2010).

This study focused on female athletes since they are at a greater risk of TBIs and they are likely to face severe consequences compared to male athletes (Covassin & Elbin, 2010; Dick, 2009). Covassin and Elbin (2010) reported that gender is an important determinant of the risk and the effects of TBI among athletes. The researchers noted that female athletes seem to be at a greater risk of TBI and they suffer severely from such injuries. The analysis of TBI and return to activity is also mediated by gender (Broshek et al., 2005). Covassin et al. (2012) provided neurocognitive scores about female athletes. They showed that the symptoms exhibited by concussed individuals differ based on age and sex. Dick (2009) also noted that there is gender variability in the post-TBI outcome among the athletes.

This study is informed by the evidence that shows increased incidences of TBIs among female soccer players (Covassin et al., 2003; Maher et al., 2014). Maher et al. (2014) conducted a study of collegiate female athletes that showed female soccer players experience TBIs at a higher rate than female basketball, lacrosse, and gymnastic players.

Strand et al. (2015) also noted that female soccer players are at a higher risk of TBI compared to nonsoccer players. Strand et al. based their conclusion on the data on the reported incidence of a TBI that was collected from 342 girls aged between 11 and 14 years old. It should be noted that Strand et al. controlled for the age and gender of the participants.

There is also a need to note that the number of female soccer athletes is on the increase, which made this study timely and relevant (Zuckerman et al., 2012). Title IX of the U.S. Education Amendments of 1972 has emerged women athletics and educational opportunities. The number of female athletes has exponentially increased since the passing of Title IX (Zuckerman et al., 2012). The number of female athletes who participate in soccer has also increased in National Collegiate Athletic Association (NCAA) schools (Zuckerman et al., 2012). The increase in the number of female soccer players, therefore, increases the number of female athletes who are at risk of TBI given the evidence that shows that soccer predisposes athletes to high risk of TBI (Lipton et al., 2013; Zuckerman et al., 2012). There is, therefore, a need to focus on cases of TBIs among female soccer players.

Despite the highlighted high risk of concussion cases among female soccer players, cases of TBI remain to be underreported among female athletes (McDonald et al., 2016). Underreporting of initial exposure to TBI among female athletes subjects them to the risk of a repeated TBI that is associated with adverse effects (McDonald et al., 2016). The researchers noted that the failure to report the initial cases of TBI by female athletes is associated with the lack of education on how to identify such cases and the sign and symptoms associated with traumatic brain injuries. According to O'Kane et al. (2014) there are limited studies that address TBIs among college athletes. O'Kane et al. argued that there is a need to focus on female soccer players since the group has a greater rate of TBI. According to O'Kane et al., more than 50 % of the collegiate female soccer players who have had TBIs continued to play with the symptoms, which predispose them to more serious consequences in the case of a subsequent TBI.

It should be noted that there are some researchers who challenge the presence of gender-based disparity in the TBI outcome among athletes (Green et al., 2018; Zuckerman et al., 2012). However, the contradicting researchers seem to have limitations in their studies that challenge the validity of their conclusion. Green et al. (2018) only included 5 female participants among the 21 who took part in the research. Zuckerman et al.'s (2012) developed their study based on what the researchers noted as controversy regarding the possible gender-related disparity in post-TBI outcomes. In conclusion, Zuckerman et al. highlighted the need for future researchers to be sport-specific while investigating post-TBI, since gender difference can exist in one game but not the other.

Various steps have been taken to address TBIs among student-athletes. The NCAA member schools play a key role in the evaluation and the management of the impact of TBI and repetitive head impacts (Carll et al., 2010). In the last 15 years, the NCAA member schools have collected and documented data on TBIs (Kerr et al., 2017). The documentation of data and research into TBI is facilitated by a landmark multimillion-dollar NCAA-DoD Grand Alliance, which aim at improving the culture of TBI reporting (Broglio et al., 2017). According to Iverson et al. (2005), NCAA member schools carry out neurocognitive testing in athletic programs using Immediate Post Concussion Assessment and Cognitive Testing (ImPACT Application, INC), which is a computerized testing program that is designed for the management of TBIs in sports (Crook, 2018; Mayers & Redick, 2012). The ImPACT program involves a baseline testing where neurocognitive testing is carried out before injury and is usually conducted before the season begins. The test (post injury testing) is also administered after an athlete sustains a TBI. The baseline and the post injury testing composite scores are then compared to determine the presence of neurocognitive function alteration (Crook, 2018; McCrory et al., 2017). The number of colleges and high schools that administer ImPACT is about 1,209 (Covassin et al., 2009).

Various researchers have used ImPACT scores to effectively analyze and report on the neurocognitive impact of TBI (Colvin et al., 2009; Covassin et al., 2012). Colvin et al. (2009) used the ImPACT scores in the evaluation of the effect of TBI on the reaction times among concussed females compared to their male counterparts. Covassin et al. (2012) used the ImPACT scores in the evaluation of the effect of TBI on the visual working memory among concussed females. Iverson et al. (2003) used ImPACT to test the cognitive performance of healthy individuals and reported a Pearson's test–retest reliabilities of between $r = .65$ and .86, which is regarded as high. Schatz (2010) reported moderate to high Pearson's correlation values of $r = .30$ to .60.

In summary, the background literature has shown a shallow perspective of collegiate female soccer athletes explored in concussion research, which has created a research opportunity in this study to enhance efforts to highlight cognitive impairment differences of reaction time and verbal working memory in collegiate female soccer athletes. Due to little depth in the literature towards at-risk collegiate female soccer athletes that experience a sport TBI, neurocognitive deficit differences in reaction time and verbal working memory, was important to identify and address in the problem statement and highlighted to fill the literature gap in subsequent sections.

Problem Statement

The problem that this study addressed related to the neurocognitive deficits experienced by concussed female athletes in collegiate sport. Researchers have shown that individuals who suffer repeated TBIs have the risk of developing long-term neurocognitive deficits such as decline in reaction time and verbal memory, which could be detrimental to the learning process among students and overall quality of life (Covassin et al., 2008). According to Jorgensen et al. (2018), TBIs have become of increased concern over the last decade, in part due to sport-related traumatic brain injuries. Previous researchers showed that TBIs are prevalent in organized collegiate athletics (Galetta, et al., 2015; Olson, 2014; Putukian et al., 2015). Previous researchers observed that in organized collegiate athletics, sport related TBIs were assessed through comprehensive TBI protocols, such as the ImPACT baseline and post injury TBI evaluation, to collect and assess injuries and cognitive domains (Broglio et al. 2017; Bruce & Echemendia, 2009). Such data has shown a gender disparity of TBIs among female student-athletes (Covassin et al., 2018). According to Hu et al. (2015), soccer players have the highest rate of TBIs in all women's NCAA sports. Female soccer players have significantly higher TBI rates than males (Maher et al., 2014). This is problematic as collegiate women athletics lack studies that focus on TBI injury data, which may pose potentially dangerous problems of unknown injuries, impairments, and neurocognitive deficits.

The current literature paints a shallow perspective towards at-risk collegiate female TBI impairments and comparisons, due to a lack of female studies and small samples (Covassin et al., 2018). Cognitive deficit symptoms continue to exist even after 10 days following a TBI, as well as these athletes are also susceptible to experience long term sequelae associated with post-TBI symptoms (Covassin et al., 2008). Concussion studies have led to understanding long term cognitive deficit symptoms in male athletes, such as memory loss, attention, language, visual impairments, and thought processing problems (Fazio et al., 2007), but few studies have focused on comparing neurocognitive deficit symptoms among females in collegiate sport who have experiences of TBI. Since studies have found that females have demonstrated severe declines in measures of reaction time and verbal memory, further research is needed in multiple sports, such as soccer and lacrosse (Covassin et al., 2008). Covassin, et al. (2012) found that future research in age differences in memory deficits after sustaining multiple sport-related traumatic brain injuries is a needed focus. The focus on the variation in the memory deficiency among individuals of different age groups was important in this study given the reported potential difference in the symptoms associated with concussion differ based on age (Covassin et al., 2012). Therefore, a study regarding the age-related differences in memory deficits is warranted to research insights into age specific TBI management.

Purpose of the Study

The purpose of this quantitative study was to explore the literature gap regarding the association between experiences of TBI among NCAA collegiate women soccer players and neurocognitive deficit symptoms of reaction time and verbal memory. The data were obtained from the ImPACT post injury assessment. The age of the female collegiate soccer players was taken into consideration when assessing the association between collegiate women soccer players and neurocognitive deficit symptoms of reaction time and verbal memory.

Research Questions and Hypotheses

The research questions and hypotheses were presented in descriptive statistics, paired *t* tests, or tests using an ANOVA type analysis by comparing the means of the groups. The study was guided by the following research questions (RQs) and hypotheses:

RQ1: Based on executive functioning factors of theory of mind, are there significant baseline and post injury differences in reaction time between NCAA collegiate female student-athlete soccer players after experiencing a head injury?

$H_0$1- There are no significant differences in reaction times among NCAA collegiate female student-athlete soccer players after experiencing a head injury.

H_a1 -There are significant differences in reaction times among NCAA collegiate female student-athlete soccer players after experiencing a head injury.

RQ2: Based on executive functioning of theory of mind, are there significant baseline and post injury differences in verbal working memory deficits between NCAA collegiate female student-athlete soccer players after experiencing a head injury?

H$_0$2- There are no significant differences in verbal working memory among NCAA collegiate female student-athlete soccer players after experiencing a head injury.

*H*a2 -There are significant differences in verbal working memory among NCAA collegiate female student-athlete soccer players after experiencing a head injury.

RQ$_3$: Based on executive functioning factors of theory of mind, are there significant baseline and post injury differences in reaction time when comparing age groups between NCAA collegiate female student-athlete soccer players after experiencing a head injury?

H$_0$3-There are no significant differences between baseline and post injury in reaction times when comparing age groups between NCAA collegiate female student-athlete soccer players after experiencing a head injury.

Ha3-There are significant differences between baseline and post injury in reaction times when comparing age groups between NCAA collegiate female student-athlete soccer players after experiencing a head injury.

RQ$_4$: Based on executive functioning of theory of mind, are there significant baseline and post injury differences in verbal working memory deficits when comparing age groups between NCAA collegiate female student-athlete soccer players after experiencing a head injury?

H$_0$4-There are no significant differences between baseline and post injury in verbal working memory when comparing age groups between NCAA collegiate female student-athlete soccer players after experiencing a head injury.

H_a4 -There are significant differences between baseline and post injury in verbal working memory when comparing age groups between NCAA collegiate female student-athlete soccer players after experiencing a head injury.

Theoretical Framework for the Study

The theory of mind (ToM) provided the theoretical basis that anchored the study. The theory of mind is defined as the cognitive, affective, and social capacity to attribute one owns mental state, as well as having the inference of another person's mental state (Bellerose et al., 2017). Based on the theory, the relationship between the effects of TBI on cognitive performance can be understood and studied (Bellerose et al., 2017; Wang & Su, 2013). One of the important abilities of the theory of mind, which was relevant to the study, is its relationship with executive functioning (Austin et al., 2014). The significance of executive functioning to the study was based on its focus on processes that regulates thought and action (Austin et al., 2014). Executive function's subcomponents such as updating of working memory are also important in understanding the connection between women collegiate sports and neurocognitive deficit symptoms of reaction time and verbal memory (Honan et al., 2015).

Nature of the Study

The nature of this study was a quantitative approach. Quantitative research allowed this study to be objective, unbiased, and reliable (Choy, 2014). The study's design was based upon a retrospective cohort research approach, which permitted me to follow the group of collegiate female student soccer athletes and determined the effect of multiple head injuries on reaction time and their verbal working memory. The retrospective nature of the study meant that the baseline data were made up of the experiences relating to reaction time and verbal working memory before suffering multiple head injuries (Lee et al., 2016). The archival baseline data were collected preseason before any diagnosis of a TBI was made. The data were readily available on the ImPACT website database however, I received a de-identified secondary database from a private researcher who received data from the ImPACT database. The study had two dependent variables, which are neurocognitive performance on reaction time and verbal working memory and independent variables of TBI history and the collegiate age groups. The four hypotheses were presented in descriptive statistics, paired *t*-tests, or test using an ANOVA type analysis and the means of the groups were compared. Due to the categorical nature of the dependent variables and the interval nature of independent variables, I thought a linear regression might have been a good statistical approach (Laerd Statistics, 2015), however, assumptions presented themselves and nonparametric *t* tests were performed.

Operational Definitions

The study consisted of two dependent variables, which were continuous variables that were scored as composite scores. The first dependent variable was the reaction time, which referred to the duration that an individual took to respond after perceiving a stimulant (Jakobsen et al., 2011). The second dependent variable was the verbal working memory which referred to short-term memory mechanisms that facilitated the retention of speech-related information for a short period and allows the verbalized information to be retrieved and used (Marvel & Desmond, 2016).

The study also considered only one independent variable, the experiences of traumatic brain injuries. The variable was defined based on the presence or the lack of experiences of traumatic brain injuries. The independent variable was therefore a "categorical variable" (Laerd Statistics, 2017). Given that the study only included participants who had experienced a TBI, the independent variable was defined based on the period before and after the participants experienced the TBI (Crook, 2018; McCrory et al., 2017).

Assumptions

The first assumption in the study was the archival data that was retrieved from a private researcher's ImPACT database and what was represented. This assumption was based that ImPACT tools do not discriminate participants based on gender or ethnicity and it is used by more than 1,616 athletes in 779 high schools and colleges in the US (Covassin et al., 2012). This assumption enabled the study to achieve generalizability by ensuring that the data were from the population of all female soccer players who have experienced traumatic brain injuries. The second assumption was that the female soccer players who experienced a TBI were those who took the baseline ImPACT. This assumption was based on the access that ImPACT was voluntary and freely available to students in NCAA schools (Crook, 2018; McCrory et al., 2017). The third assumption was that the ImPACT tests match the participants' symptoms, otherwise the tests risk providing inaccurate predictions and conclusions (Crook, 2018). The second and third assumptions enabled the study to compare neurocognitive performance before and post-TBI experiences based on ImPACT composite scores.

Scope and Delimitations

The assessments of the impact of TBI on neurocognitive function focused only on reaction time and verbal working memory. The two features of neurocognitive functioning were chosen because there were the frequently reported effects of TBIs (McInnes et al., 2017). The effects on reaction time and verbal working memory also resulted in adverse effects on student academics, sporting career and overall quality of life (Ransom et al., 2015; Yengo-Kahn et al., 2016). The study focused only on collegiate female student-athletes and I restricted only to the student-athletes who actively participated in college soccer. Only the students who were enrolled in NCAA schools and who took ImPACT assessments were included in the study. The study, therefore, was generalizable to NCAA female collegiate student-athletes who played soccer.

Limitations

One of the likely limitations associated with the ImPACT tool was the low reliability and validity. This concern was based on the concerns raised by previous researchers (Broglio et al. 2007; Schatz, 2010). It should however be noted that other researchers have reported that the tool has high reliability with Cronbach's alpha coefficient between α=.65 and α=.86 (Lovell & Collins, 2003; Mayers & Redick, 2012). Therefore, in this study, I carried out Cronbach's alpha reliability test to determine the reliability. The other limitation in this study was the decision to use only the schools that were listed on the ImPACT Web site without including those in the other websites that offer computer-based neurocognitive tests such as HeadMinder. Although this study only focused on data from ImPACT tests, it should be noted that the ImPACT data have high representativeness (Covassin et al., 2009). Since this study manipulated a few variables, it was challenging to control variables such as pre-existing variations in the neurocognitive performances among students.

Significance

The study addressed the research gap of NCAA collegiate female soccer athletes, TBI history, neurocognitive performance comparisons between reaction time, verbal memory, and the age of the collegiate female soccer athlete. Past studies have focused on either incidence injury rates and self-reported symptoms of TBIs separately, instead of comparing relevant variables as a group or from a computerized neurocognitive assessment (Olson, 2014). Furthermore, the significance of this study focused on how sport related TBIs impact collegiate female soccer athletes differently through comparing reaction time and verbal working memory testing scores by sport, age, and TBI history. Social change implications for this study aids in addressing the findings and results that may further analyze and design collegiate TBI protocol programs, by improving and offering specific healthy resolutions to collegiate athletic program policies. The results can translate to provide much needed insight for the individual player. Collegiate female athletes can benefit from TBI education and understand the importance how symptoms can affect negative cognitive domains if not managed properly.

Summary

This chapter introduced the study's perspective by discussing pertinent information from the existing literature. It is evident that TBIs are prevalent especially among collegiate female soccer players. However, little has been done to evaluate the neurocognitive challenges that collegiate female soccer players face. The information provided in this chapter included important factors explaining ImPACT assessment values of neurocognitive functioning and the challenges of reaction time and verbal working memory among female soccer players who experienced TBIs. This chapter explained the resource and access to the ImPACT database of neurocognitive tests that are performed by students before and after traumatic brain injuries and how the theory of mind provided a theoretical basis upon the study's evaluation of the cognitive effects associated with traumatic brain injuries. After using the ImPACT data and guide by the theory of mind, it was possible to carry out a quantitative research of the experiences of TBI among collegiate female soccer athletes and neurocognitive deficit symptoms of reaction time and verbal memory. In chapter 2, the study provides a further evaluation of the relevant existing literature and the literature of the theory of mind. Chapter 2 also provides further description of the research gap addressed in this study. Chapter 3 provides an approach that was used in testing the identified hypotheses.

Chapter 2: Literature Review

Introduction

The literature review provided an in-depth analysis of existing knowledge and practice that related to the topic of interest, which are reaction times and verbal working memory outcomes among NCAA collegiate female student-athlete soccer players with experiences of traumatic brain injuries. This section provided evidence that anchored the study within the existing literature and describes the study's theoretical framework. In this study I found evidence that led to the identification of the literature gap, which formed the focus of the study.

In this section, I review evidence from peer-reviewed articles and official websites. The articles were retrieved from relevant electronic databases over the last 5 years from academic searches completed in Biomed Central, Data USA, EBSCO. Google Scholar, Pubmed, Medline, ProQuest, PsycArticles, PsycINFO, and Sage Journal. The retrieval of the articles from the electronic databases was carried out using specific keywords, which included the following: concussion, traumatic brain injuries, mild traumatic brain injuries, neurocognitive performance, ImPACT, NCAA, college soccer, and female athletes. Government data and statistics from the US Department of Human and Health Services provided injury and prevention data through operational offices of Centers for Disease Control and Prevention (CDC). The relevant theoretical framework is described in the first section, and the various themes are described in the subsequent sections. The themes that are discussed include the definition and prevalence of traumatic brain injuries, effects of concussion, concussion outcomes among female athletes, measurement of the postconcussion outcomes and finally the gap in the literature.

Theoretical Framework

The theory of mind (ToM) addresses the theoretical basis of various concepts and evidence to understand and interpret the study's framework. The theory of mind is defined as the cognitive, affective, and social capacity to attribute one owns the mental state, as well as having the inference of another person's mental state (Bellerose et al., 2017). Based on the theory, the relationship between the effects of TBI on cognitive performance can be understood and studied (Bellerose et al., 2017; Wang & Su, 2013). One of the important abilities of the ToM, which was relevant to this study, is its relationship with executive functioning (Austin et al., 2014). The significance of executive functioning was based on its focus on the process that regulates thought and action (Austin et al., 2014). Executive function's subcomponents such as updating of working memory are also important in understanding the relationship between women's collegiate sports and neurocognitive deficit symptoms of reaction time and verbal memory (Honan et al., 2015).

Bellerose et al. (2015) examined the effects of TBI based on ToM. The researchers noted that the children with a history of traumatic head injuries had difficulties in the emotion, desires, and false-belief tasks. However, Bellerose et al. (2015) did not establish any correlation between ToM and the characteristics associated with the traumatic head injuries suffered by the children. It should be noted that the results reported by Bellerose et al. were observed after controlling for the preinjury externalizing behavior. Bellerose et al.'s study was based on 41 children with a history of head injuries and 50 without a history of injuries. However, Bellerose et al. only focused on the mild traumatic head injuries, which therefore limited the generalization of their results to other forms of injuries.

Literature Review to Key Variables and Concepts

Definition and Prevalence of Traumatic Brain Injuries

Traumatic brain injury refers to the injury to the brain caused by an external force and which results in alterations in the cognitive or behavioral functioning (Roebuck-Spencer & Cernich, 2014). Traumatic brain injury can also be defined as the traumatically induced structural injury and/or physiological disruption of brain function that is caused by an external force (p. 4). Traumatic brain injuries vary based on the degree of injury and the associated effects/outcomes (Roebuck-Spencer & Cernich, 2014). The time taken by a concussed individual to regain consciousness were also used to classify traumatic head injuries. The injuries were categorized into three groups, which included mild, moderate, and severe injuries (Roebuck-Spencer & Cernich, 2014).

The classification of the severity of traumatic brain injuries were mainly based on the Glasgow Coma Scale (GCS; Teasdale & Jennett, 1974) score, which were usually taken at or just after the injury and provides the depth of one's unconsciousness and response to stimuli (Roebuck-Spencer & Cernich, 2014). The highest Glasgow Coma Scale (GCS; Teasdale & Jennett, 1974) score was 15 while the lowest was three, the injuries with a score of eight or lower were considered as severe (Roebuck-Spencer & Cernich, 2014). Individuals with scores of 9 to 12 were classified as having moderate traumatic brain injuries while the injuries with a score of 13 and above were categorized as mild traumatic brain injuries (Roebuck-Spencer & Cernich, 2014).

Concussion is a term that has been used to refer to mild traumatic brain injuries, which are the most prevalent form of traumatic brain injuries (McInnes et al., 2017). Traumatic brain injuries are associated with impaired cognitive function, which can resolve after 3 months (McInnes et al., 2017). However, for some individuals, the cognitive damage caused by TBI can take longer to resolve (Daneshvar et al., 2011; Hall et al., 2005). Persistent post-concussion syndrome is a term that is used to describe the prolonged symptoms of concussion (Daneshvar et al., 2011, Marshall et al., 2015). It is estimated that about 15% of the individuals who suffer concussion for the first time end up with persistent post concussion syndrome (McInnes et al., 2017; Spinos et al., 2010).

Traumatic brain injuries are prevalent among males and female athletes and are considered one of the leading causes of death (Roebuck-Spencer & Cernich, 2014). In the United States of America, about 3.8 million individuals suffer traumatic brain injuries each year (Zuckerman et al., 2012). Evidence also indicated that almost 1,364,797 succumb to traumatic brain injuries. The injuries also contributed to 30.5 % of the deaths (Roebuck-Spencer & Cernich, 2014). However, it should be noted that the various studies report varying findings on the incidence of TBI, which could be due to the difference in the methodological approach adopted by the studies (Roebuck-Spencer & Cernich, 2014). There is however agreement among the different researchers that there is an upward trend in the number of TBI reported each year (Roebuck-Spencer & Cernich, 2014).

Athletes have a high risk of concussions (Yang & Baugh, 2016). Up to 1.6 million cases of concussions per year in the United States are associated with different sports and recreational activities. Given that over 44 million young Americans participate in some form of organized sport, it is important to focus on the occurrence of concussion and the potential negative effects (Yang & Baugh, 2016). The prevalence of traumatic brain injuries varies across different sports. Soccer is one of the sports with a high risk of exposure to concussion (Yang & Baugh, 2016). In an examination of neurocognitive performances, Lipton et al. (2013) reported that the heading of the ball among soccer players are associated with an increased risk of poor neurocognitive performance. Lipton et al. based their conclusion that included 37 amateur soccer players. Researchers also reported that each year there are about 50,000 cases of soccer-related concussions among high school athletes (O'Kane et al., 2014). The fact that soccer is associated with a high prevalence of concussion is a serious threat since the sport is the fastest growing sport (Maher et al., 2014). In the US and Canada alone, it is estimated that there are about 27 million soccer players. According to Strand et al. (2015), female soccer players are at a higher risk of concussion compared to the non-soccer players. Strand et al. (2015) based their conclusion on the data on the reported incidence of concussion that was collected from 342 girls aged between 11 and 14 years old. I also wanted to note that Strand et al. (2015) controlled for the age and gender of the participants.

Sahler and Greenwald (2012) argued that the prevalence of traumatic brain injuries is set to increase as the number of students joining college and high school sports increases. According to Sahler and Greenwald (2012), for effective management of concussion to be realized, it is important to evaluate the symptoms and carry out neurocognitive testing. The researchers indicated serial testing need to be carried out during weeks, even months of recovery.

Effects of TBI

The cognitive impairments that result from TBI have a significant effect on the long-term well-being of an individual (Rabinowitz & Levin, 2014). The various cognitive domains that are affected by concussion include the executive function, learning and memory, attention, and the processing speed (McInnes et al., 2017; Rabinowitz & Levin, 2014). The disruption in the nervous system that controls the cognitive functions is responsible for the effects of concussion on cognitive function and other behavioral defects that adversely affect the quality of life among the affected individuals (Danna-Dos-Santos et al., 2018; McInnes et al., 2017). The delayed reaction times due to injuries caused by concussion have been associated with adverse downstream effects which include but not limited to response under pressure, verbal memory, and executive function (Dymowski et al., 2015; Miotto et al., 2010; Woods et al., 2015).

Danna-Dos-Santos et al. (2018) reported in their study that involved the analysis of data from 72 individuals with a mean age of 25.7 years, that concussions have adverse effects on the ability of individuals to react to environmental stimulants. The researchers of the study noted that the affected individuals had longer reaction times to visual and auditory stimulants. Danna-Dos-Santos et al. (2018) assessed the reaction time using a single stimulant, which involved the use of a single laser projection that lasted for 2 seconds. The participants reacted by immediately pressing the instrumented button using the thumb of their preferred hand. The researchers varied the time to take to produce the stimuli to prevent the participants from anticipating. Danna-Dos-Santos et al. (2018) attributed their observations to the defects caused by concussion on the corpus callosum. Womack et al., (2017) also reported a longer reaction time among 23 patients who suffered concussion. However, Womack et al. (2017) examined the patients within 24 hours of suffering concussion. The researchers, therefore, did not provide evidence on the long-term effects of concussion. Womack et al.'s (2017) study is however important since it was able to link the longer reaction time to the disruption of the white matter caused by concussion.

Concussion is also associated with chronic cognitive-linguistic deficits that have adverse effects on the verbal working memory (Wood & Wolgemuth, 2019). The research that Green et al. (2018) carried out, noted that individuals who had suffered concussions had poor verbal working memory outcomes compared to those without a history of concussions. Green et al. (2018) based their conclusion on the data that were collected from 21 youths aged between 10 and 14-years-old. The participants took a verbal working memory test that also examined the performance based on accuracy and number of false alarms and misses. Green et al. (2018) noted that the participants with concussion were more likely to have false alarms, misses, and lower verbal working memory accuracy. It should, however, be noted that Green et al. (2018) did not distinguish whether the gender of the participants influenced the observed findings. It should also be noted that Green et al. (2018) only included 5 female participants among the 21 who took part in the research.

The study that was carried out by Covassin et al. (2010) reported that concussion could cause poor cognitive performance that can last for weeks. According to Covassin et al. (2010), the time the concussed athletes took to return to the baseline (recover) was important to the physician. The researchers based their conclusion on the data that were collected from a cohort of 200 athletes that was sampled from 8 high schools in Michigan. Covassin et al. (2010) focused on the determination of whether there is a difference between the baseline and post-concussion cognitive performance. Covassin et al. (2010) administered ImPACT to the participants on the second day after concussion, 1 week, 2 weeks and 3 weeks post-concussion and on the 30th day. Covassin et al. (2010) noted poor reaction times among the 72 athletes that reported concussion, which lasted up to the 14th day. They further documented that the concussed athletes were only able to return to the baseline on the 21st day. Covassin et al. (2010) also reported poor verbal memory performance among the concussed individuals, which only returned to the baseline on the 14th day. The findings by Covassin et al. (2010) supported the conclusions made by McClincy et al. (2006) who reported that it took about a week or two for concussed individuals' cognitive performance to return to the baseline. However, Pellman et al. (2006) reported that high school-aged, concussed athletes took more time to return to the baseline compared to the collegiate athletes, which suggested the need to consider mediating factors in the management of concussion.

Concussion and Associated Outcomes Among Female Athletes

According to Covassin and Elbin (2010), one of the mediating factors that needed to be considered when evaluating and managing concussion is gender. Researchers argued that the effects and the inherent risk of concussion vary based on gender with female athletes being more disadvantaged compared to male athletes. Covassin and Elbin (2010) also highlighted evidence that suggested that brain function varies between males and females and the variation could affect response to concussion. The exponential increase in the number of female athletes started with the passing of Title IX in 1972 (Zuckerman et al., 2012). It is estimated that the number of female high athletes has increased from 1.9 million to 3.8 million within 10 years since 1990 (Zuckerman et al., 2012). Increased participation of female athletes in high school soccer has seen an increase in the number of NCAA schools increase by 617 programs, which is the highest increase of any female collegiate sport (Zuckerman et al., 2012).

Broshek et al. (2005) also suggested that gender is an important mediating factor in the analysis and management of concussion and return to activity. Broshek et al. reported that females have significantly slower reaction times compared to male athletes. Broshek et al.'s study involved 2,340 participants from both genders who were sampled from high schools and colleges in the US. All the participants completed baseline neurocognitive computerized testing before the start of the season and those who sustained a concussion (n=155) were reevaluated.

Some researchers have suggested that female athletes suffer a high percentage of concussion compared to male athletes. Covassin et al. (2003) assessed data collected from 14,591 collegiate athletes. The study reported that the female soccer athletes had a significantly higher frequency of concussion compared to the male counterparts. Covassin et al. (2003) obtained the participants from the NCAA Injury Surveillance

System. Although Covassin et al.’s (2003) study was based on an old dataset (1997-2000), the study raised questions about whether a similar trend continues to be reported.

It is evident that many studies support the high prevalence of concussion among female athletes. However, according to Maher et al.'s (2014) meta-analysis that focused on the analysis of a total of 13 articles on concussion among soccer athletes, the incidence of concussion among soccer players seemed not to vary based on gender. The researchers noted that only one of the seven articles that assessed the frequency of concussion based on gender reported differences with males having a higher incidence.

It should be noted that concussion is underreported among female athletes. According to the study that was carried out by McDonald et al. (2016), most of the female athletes who suffer concussion do not report the sign and symptoms associated with concussion. McDonald et al. (2016) based their concussion on the data that was collected from 77 female athletes from 14 high schools. The researchers noted that nearly 50 % of the athletes reported to have had suspected conclusion but only a third of them reported the concussion. The failure to report could be due to the lack of education since just 66 % of the athletes indicated that they had received concussion education.

O’Kane et al. (2014) argued that although steps have been taken to address concussion in sport, there are limited studies that address the issue among college athletes. The researchers particularly noted the limited research on concussion among female soccer players. O’Kane et al.'s (2014) noted that there is a need to address concussion among the female soccer players since the group has a greater rate of concussion. According to O’Kane et al.'s (2014), concussion among soccer players is mainly due to the heading of the ball. The researchers based their conclusions on the data that was collected from a prospective cohort of 351 female soccer players aged between 11 and 14-years-old. O'Kane et al.'s (2014) noted that there were 59 cases of concussions and only half of the affected athletes sought medical care while 58.6 % of them continued to play with concussion symptoms.

Colvin et al. (2009) also reported slower reaction times among concussed females compared to their male counterparts. The researchers based their conclusion on their cohort study that included 234 athletes aged 8 years to 24 years. Among the participants, 141 were females while the rest were males. They all completed the ImPACT test battery. Colvin et al. (2009) concluded that there is a need to consider of the concussed athlete when assessing the recovery. In another study, which focused on the assessment of the visual working memory, Covassin et al. (2012) noted that female athletes had higher performance compared to their male counterparts. Based on their cross-sectional study that involved 1,616 athletes from 837 colleges and 779 high schools in the US, Covassin et al. (2012) noted that females outperformed males in verbal memory scores. Covassin et al.'s (2012) study participants completed ImPACT, a symptom inventory, and the Beck Depression Inventory II (BDI-II). In a study that provided a summary of 16 years of NCAA data from 1988, Hootman et al. (2007) also reported that concussions accounted for the highest number of injuries in women soccer.

Dick (2009) also concluded in their systematic review that female athletes are at a greater risk of concussion compared to male athletes. The researcher noted that there has been a consistent reporting of higher frequency of concussion among female athletes despite the change in the methodological approach over the years. Dick (2009) also suggested that there is gender variability in the post-concussion outcome among the athletes, which suggests the need to carry research on female and male athletes. The conclusion made by Dick (2009) was based on the data that was retrieved from 51 articles, from which six assessed concussions and related challenges among soccer athletes.

However, the study that was carried by Zuckerman et al. (2012) did not support Dick’s (2009) conclusion regarding gender variability in post-concussion. Zuckerman et al. (2012) noted that the changes in the verbal and visual memory following concussion did not vary based on gender. Zuckerman et al. (2012) based their conclusion on the data that were collected from 80 soccer athletes (40 males and 40 females). Zuckerman et al. (2012) collected the data relating to verbal and visual memory before and after concussion using ImPACT. It should, however, be noted that Zuckerman et al.'s (2012) study was developed based on what the researchers noted as controversy regarding the possible gender-related disparity in post-concussion outcomes. In conclusion, Zuckerman et al.'s (2012) highlighted the need for future researchers to be sport-specific while investigating post-concussions since gender differences can exist in one game but not the other.

Different explanations attempt to justify the role of gender in brain function and the cognitive performance outcomes associated with concussion (Covassin & Elbin, 2010). Various researchers have highlighted the difference in chemical, anatomical and organizational differences in the brain between males and females as the main cause of the difference in the response to concussion (Covassin & Elbin, 2010; Tierney et al., 2005; Tierney et al., 2008). The chemicals that are involved in memory and information processing such as neutrophils are more among females (Covassin & Elbin, 2010). Covassin and Elbin (2010) also argued that the difference in the cognitive strengths and weaknesses that exist between males and females could also influence the cognitive outcome following a concussion.

As a means of addressing the gap in knowledge regarding the effect of concussion among the female athletes, Chamard et al. (2016) researched on how the injuries sustained by concussed female athletes affect selected sections of their brains. Based on the data that were collected from 10 female athletes who had experienced a concussion in the previous 6 months, Chamard et al. (2016) noted alterations in the corpus callosum, which is the portion of the brain that is responsible for cognitive function. However, Chamard et al. (2016) did not carry out experiments to determine whether the observed changes in the corpus callosum resulted in the altered cognitive function.

Measurement of the Post Concussion Outcomes

The combination of symptoms with neurocognitive testing provided a more sensitive approach in the identification of impairment caused by concussion and in decision making regarding return to activity (Sahler & Greenwald, 2012). One of the ways through which cognitive function can be determined is through the assessment of the information processing ability (Danna-Dos-Santos et al., 2018; Norman, Shah & Turkstra, 2019). Various studies operationalized speed based on the analysis of reaction time (Danna-Dos-Santos et al., 2018; Norman et al., 2019; Womack et al., 2017). The experiments that assessed the reaction time included the symbol-digit test (Draper & Ponsford, 2008), the Stroop test (Ben-David et al., 2014) and tests of attention (Ríos et al., 2004). The use of reaction time assessment in the determination of cognitive processing ability was a reliable and accepted approach among individuals with or without concussion (Norman et al., 2019). Evidence provided by 49 subjects showed that over 83 % of the student-athletes who had suffered concussion had lower neurocognitive scores compared to the baseline score while the control group showed no reduction in the scores.

Various approaches have been used in the measurement of the long term and short-term neurocognitive impairments associated with concussion. One of the tools is the computerized neuropsychological testing such as the ImPACT assessment battery (Mayers & Redick, 2012). It should be noted that there are other tools used in the determination of the baseline neurocognitive performance. Some of the other tools include the Brain Injury Screening Questionnaire, Concussion Resolution Index, and the Standardized Assessment of Concussion (Sahler & Greenwald, 2012). The advantages associated with computerized neurocognitive testing include the need for minimal human resources and its cost-effectiveness (Sahler & Greenwald, 2012). Computerized approaches also allow the building of a database on the concussion and athletes' safety (Sahler & Greenwald, 2012). According to McCrory et al. (2009), the Zurich consensus guidelines recognize the neurocognitive assessment as vital in the identification and management of concussion. Zurich consensus guidelines provide a basis upon which sport-related concussions are conceptualized (McCrory et al., 2017). The guidelines are meant to guide physicians and other caregivers who are involved in athlete care (McCrory et al., 2017).

According to McCrory et al. (2009), computerized approaches such as ImPACT are ideal for the testing of baseline neurocognitive performance. As indicated in the ImPACT official page located at www.impactconcussion.com, the tool is FDA approved and has been used in schools, healthcare organizations, and sports organizations to assess and manage a concussion. ImPACT's baseline testing is used to document the functioning of the healthy brain before concussion (www.impactconcussion.com). ImPACT post injury neurocognitive tests are used to understand the status of the injury in relation to cognitive activity. Comparison between the baseline and the post injury assessment is important in making of concussion treatment decisions. For the case of active athletes (only for those aged between 12 and 59 years), ImPACT guides the decision on whether the previously concussed athletes are ready to return to activity (www.impactconcussion.com). It should, however, be noted that it is not a must for the health care practitioners to have baseline ImPACT for individual patients. Management care can still be offered based on the ImPACT's age-specific test scores as the comparison (Crook, 2018). The ImPACT is regarded as an easy to do test, which takes only 20 minutes. However, one needs to have a laptop with an Internet connection (Elbin et al., 2019). It should also be noted that only qualified healthcare practitioners are mandated to administer post injury ImPACT (Elbin et al., 2019).

There are three main sections that makeup ImPACT with one of them being the section of demographics and the health history information. The second part is made up of a questionnaire that has 22 questions. The third section is made up of six test modules that assess the reaction time, visual memory, processing speed, and verbal memory (Mayers & Redick, 2012). The data from the ImPACT enables the sports administrators to decide on the safety of the concussed individuals, especially to decide when the concussed individual should return to active sport or limit playing time (Mayers & Redick, 2012).

According to Crook (2018), the ImPACT tool is a scientifically validated approach that has been widely used in the measurement of the outcomes associated with concussion. Crook (2018) argued that ImPACT is a gold standard test in the assessment and management of the concussion. It is estimated that over 7.5 million people have taken an ImPACT test, which makes the tool frequently used in the management of concussion (Crook, 2018). As many as 1209 colleges and high schools use ImPACT (Covassin et al., 2009). The tool is also used by professional associations and teams globally (Mayers & Redick, 2012). Evidence suggests that over 250 peer-reviewed articles support the use of ImPACT (Crook, 2018).

The ImPACT application is considered a reliable tool. Iverson, Lovell, and Collins (2003) used ImPACT to test the cognitive performance of healthy individuals (n= 56) before and after 13 days. The researchers reported a Pearson's test–retest reliabilities of between r=.65 and .86, which is regarded as high. However, Mayers and Redick (2012) argued that the test interval period that was considered by Iverson et al. (2003) was shorter compared to the practical test interval period when using ImPACT.

According to Mayers and Redick (2012), the administration of subsequent ImPACT occured at least months or years apart.

Findings obtained by other researchers raise various questions over the reliability and validity of ImPACT. The study that was carried out by Broglio et al. (2007) reported unacceptably low Pearson's correlation values of r=.23 to .38. The researchers involved a sample of 76 healthy individuals and ImPACT was administered 45 days apart. Schatz (2010) in his assessment of concussion among 95 athletes reported moderate to high Pearson's correlation values of r=.30 to .60. Schatz (2010) administered ImPACT within an interval of 2 years. However, it should be noted that the Schatz's (2010) results were affected by large confidence intervals that suggested that ImPACT may not provide the required sensitivity when measuring true cognitive impairment. Mayers and Redick (2012) noted that one of the steps that can be taken to ensure that reliable findings are obtained when using ImPACT is by computing the reliable change confidence intervals separately based on the gender. Mayers and Redick (2012) also noted that some of the factors that affect the reliability of ImPACT are the significant practice effects, which led to the increase in the processing speeds and visual memory, especially among the controls. The improved performance occurred as a result of practice may mask the impairments associated with concussion (Mayers & Redick, 2012). It is therefore advisable that researchers control for the effects of practice when calculating the change confidence intervals (Mayers & Redick, 2012).

Despite the highlighted reliability issues, ImPACT remains the standard tool for immediate post-concussion assessment and cognitive testing (Crook, 2018). The tool is viewed as the most appropriate way of objectifying concussion severity. The need to have an objective approach to the determination of concussion severity led to the adoption of ImPACT as standard in collegiate athletics and especially by the National Collegiate Athletic Association (NCAA) (Crook, 2018). However, it should be noted that NCAA only advocates but does not mandate the use of ImPACT. According to Crook (2018), the adoption of ImPACT as the standard is due to the view that the tool is culturally competent. The tool is also supported by various scientific research and expertise, which together with the support from NCAA, position it as the preferred tool (Crook, 2018).

The NCAA Injury Surveillance Program (ISP) documents the prevalence of concussion nationwide (Kerr et al., 2017). It is projected that the NCAA has over 450,000 athletes in high schools and colleges nationwide (Carll, Park & Tortolani, 2010). The NCAA acts as a means of unifying the students' injury prevalence and monitoring of their health and well-being. In partnership with Datalys Center for Sports Injury Research and Prevention, Inc, NCAA has been able to provide data access to researchers. Interested researchers upon submitting the required data-request forms and data licensing agreement are given access to subsets of five-year data, which are available on the Web-based Injury Surveillance System. To ensure the ethical use of the data, the NCAA has assigned an external independent review committee the duty of reviewing and approving the data request documents from the researchers (Kerr et al., 2017).

Gap in Literature

The assessed evidence shows that concussion is on the rise among the athletes in college sports and especially the female soccer players. The increase in the prevalence of concussion is associated with the increased negative outcome on cognitive performance among the affected, which may adversely affect quality of life. Management of the concussion has been shown to be dependent on effective identification of concussion and associated neurocognitive effects among concussed individuals. However, obtained evidence suggests that concussed female soccer players, especially those in colleges have largely been ignored by researchers. The review that was carried out by Maher et al. (2014) noted a disparity in the reporting and the assessment of concussion and related symptoms among the female soccer players. The researchers noted that only 26 of the 49 articles that they assessed considered the female soccer players as participants. Maher et al. (2014) noted that the limited focus on concussion among female athletes should be addressed since more female athletes are taking part in soccer. The researchers, therefore, recommended that studies that exclusively focus on female soccer athletes should be carried out. Morris (2015) also argued among female sports, soccer has the highest growth of participation and is also associated with the highest number of concussions. O'Kane et al. (2014) also noted that although female soccer athletes are associated with a high risk of concussion there is little research that examines immediate and long-term effects. Furthermore, evidence shows that in collision sports such as soccer, female athletes are at a higher risk of concussion as compared to males, which therefore emphasized the need to address the gap (Abbas et al. 2015; Poole et al. 2015).

Summary

The evidence presented in this section have shown the importance of concussion among athletes and particularly, female soccer players. Prevalence of concussion has been indicated to be on the rise in college sports. Female soccer players have been shown to be at the highest risk of concussion. Assessed literature also emphasized on the importance of neurocognitive assessment in the management of concussion. However, evidence have shown that few studies have focused on comparing and evaluating verbal working memory and reaction time deficit differences among female soccer athletes and concussion history. Due to the limited research into concussed female soccer athletes and related outcomes, there is a shallow perspective towards at-risk collegiate female concussion impairments. The methodology used in this study is discussed in the subsequent section and will address the highlighted gap.

Chapter 3: Research Method

Introduction

The specific problem in this study addressed the existing gap among collegiate female soccer athletes, concussion history, and neurocognitive performance comparisons, specifically, reaction time and verbal working memory (Covassin et al., 2012). The purpose of the study was to determine whether there is a significant baseline and post injury difference in reaction time between NCAA collegiate female student-athlete soccer players after experiencing a head injury. The nature of the study was quantitative and based on the retrospective archival research approach. The adopted research approach enabled the researcher to extract evidence from archival records to determine the effect of head injuries on reaction time and verbal working memory.

In this research I examined the effect of head injuries on the reaction time and the verbal working memory among female collegiate soccer athletes. The study also established how the age of the female collegiate soccer athletes influenced the reaction time and the verbal working memory among those who suffered head injuries. This chapter provided a description of the research methodology and components of the problem and research question. The first two sections identified the problem statement and the research question. The subsequent sections provided a description of the various aspect of the research along with the rationale. The research design adopted in the study is discussed along with specific methodology. The sample is identified along with the approach used in the selection of the participants. The approach used in the collection of the data and the data collection instrument are also described. Finally, the chapter describes the approach used in the analysis of the data and relevant research ethical considerations.

Purpose of the Study

The purpose of this quantitative study was to explore the literature gap regarding the association between experiences of TBI among collegiate women soccer players and neurocognitive deficit symptoms of reaction time and verbal memory. The problem that the study addressed related to the neurocognitive deficits experienced by concussed NCAA female athletes in collegiate sport. Evidence have shown that individuals who suffer repeated TBIs have the risk of developing long-term neurocognitive deficits such as a decline in reaction time and verbal memory, which could be detrimental to the learning process among students and overall quality of life (Covassin et al, 2008). According to Jorgensen et al. (2018), TBIs have become of increased concern over the last decade, in part due to sport-related traumatic brain injuries. Previous evidence showed that TBIs are prevalent in organized collegiate athletics (Galetta, et al., 2015; Olson, 2014; Putukian et al., 2015). Previous researchers observed that in organized collegiate athletics, sport related TBIs have been assessed using comprehensive TBI protocols, such as the ImPACT baseline and post injury TBI evaluation, to collect and assess injuries and cognitive domains (Broglio et al. 2017; Bruce & Echemendia, 2009). Such data has shown a gender disparity of TBIs among female student-athletes (Covassin et al., 2018). According to Hu et al. (2015), soccer players have the highest rate of TBIs in all women's NCAA sports. Female soccer players have significantly higher TBI rates than males (Maher et al., 2014). This is problematic as collegiate women's athletics lack studies that focus on TBI injury data, which may pose potentially dangerous problems of unknown injuries, impairments, and neurocognitive deficits.

The current literature paints a shallow perspective towards at-risk collegiate female TBI impairments and comparisons, due to a lack of female studies and small samples (Covassin et al., 2018). Cognitive deficit symptoms continue to exist even after 10 days following a TBI, as well as athletes are also susceptible to experience long term sequelae associated with post-TBI symptoms (Covassin et al., 2008). Concussion studies have led to understanding long term cognitive deficit symptoms in male athletes, such as memory loss, attention, language, visual impairments, and thought processing problems (Fazio et al., 2007), but few studies have focused on comparing neurocognitive deficit symptoms among females in the collegiate sport who have experiences of TBI. Since studies have found that females have demonstrated severe declines in measures of reaction time and verbal working memory, further research is needed in multiple sports, such as soccer and lacrosse (Covassin et al., 2008). Covassin, et al. (2012) found that future research in age differences in memory deficits is a needed focus after sustaining multiple sport-related traumatic brain injuries.

The study had two dependent variables, which are neurocognitive performance on reaction time and verbal working memory and independent variables of TBI history and the collegiate age groups. A quantitative research design of statistical analysis of descriptive statistics, *t* tests, and nonparametric statistics connected the following research questions:

Research Questions and Hypotheses

The following are the research questions and hypotheses for this research study:

RQ_1: Based on executive functioning factors of the theory of mind, are there significant baseline and post injury differences in reaction time between NCAA collegiate female student-athlete soccer players after experiencing a head injury?

$H_0 1$: There are no significant differences in reaction times among NCAA collegiate female student-athlete soccer players after experiencing a head injury.

$H_a 1$: There are significant differences in reaction times among NCAA collegiate female student-athlete soccer players after experiencing a head injury.

RQ_2: Based on the executive functioning of the theory of mind, are there significant baseline and post injury differences in verbal working memory deficits between NCAA collegiate female student-athlete soccer players after experiencing a head injury?

$H_0 2$: There are no significant differences in verbal working memory among NCAA collegiate female student-athlete soccer players after experiencing a head injury.

$H_a 2$: There are significant differences in verbal working memory among NCAA collegiate female student-athlete soccer players after experiencing a head injury.

RQ_3: Based on executive functioning factors of the theory of mind, are there significant baseline and post injury differences in reaction time when comparing age groups between NCAA collegiate female student-athlete soccer players after experiencing a head injury?

$H_0 3$: There are no significant differences between baseline and post injury in reaction times when comparing age groups between NCAA collegiate female student-athlete soccer players after experiencing a head injury.

*H*a3: There are significant differences between baseline and post injury in reaction times when comparing age groups between NCAA collegiate female student-athlete soccer players after experiencing a head injury.

RQ_4: Based on executive functioning of the theory of mind, are there significant baseline and post injury differences in verbal working memory deficits when comparing age groups between NCAA collegiate female student-athlete soccer players after experiencing a head injury?

$H_0 4$: There are no significant differences between baseline and post injury in verbal working memory when comparing age groups between NCAA collegiate female student-athlete soccer players after experiencing a head injury.

*H*a4: There are significant differences between baseline and post injury in verbal working memory when comparing age groups between NCAA collegiate female student-athlete soccer players after experiencing a head injury.

Research Design

The nature of the study was quantitative. Quantitative research allowed the study to be objective, unbiased, and reliable (Choy, 2014). The research study design was based on a retrospective archival research approach. Understanding the history of records and recordkeeping systems and their use is an essential part of archival research. Archival recognition remains a convincing research method that without the contextual historical evidence, researchers cannot fully appreciate the nature and importance of issues or formulate solutions to them (Cox, 2019; Deller, 2019). This approach enabled me to extract evidence from archival records and determined the effect of head injuries on reaction time and verbal working memory. The archival methodology nature of the study meant that the records from baseline and post injury concussion assessments were gathered from a relevant dataset and interpreted from what has already been experienced by previous NCAA female soccer athletes. This historical secondary data were readily available from the ImPACT database and government websites with advantages for researcher to use greater resources and gain wider access to convincing accounts of similar data, that can replicate and compare with new hypotheses with hard to reach populations (Dufour & Richard, 2019).

The research study did not consider qualitative methodologies because unlike the quantitative approaches, the qualitative designs are highly affected by the context-based variation (Lampard & Pole, 2015). The qualitative approaches are best suited in the development of theory and contextual exploration of the research phenomenon (Lampard & Pole, 2015). Therefore, given that I used statistical approaches to obtain conclusive outcomes regarding the association between head injuries on the reaction time and the verbal working memory among female collegiate soccer athletes, the qualitative methodologies were not appropriate. However, a quantitative study allowed me to test hypotheses and describe relationships between dependent and independent variables (Johnson & Christensen, 2008).

Researchers that have examined the effect of concussion on various aspects of neurocognitive function have noted the use of quantitative research designs to be effective (Broglio et al., 2017; Broglio et al., 2018; Katz et al., 2018). The use of quantitative in the highlighted previous studies enabled objective measurement of the study variables and limited bias by ensuring that valid and reliable tools and procedures were used. It is also evident from the previous studies that quantitative approaches facilitate the use of statistical tests such as *t*-tests in the analysis of data and development of the conclusive findings relating to the relationship between study variables (Mustafi et al., 2018). The use of the quantitative methodology also allowed previous researchers to use a large sample size, which enabled studies to achieve representativeness, especially where the target population is large (Lampard & Pole, 2015).

This study used a quantitative retrospective archival research approach based on pre and posttest research design. The use of pre and posttest research designs enabled the assessment of the change in each research phenomenon (dependent variables), and result of the independent variable being studied. The use of paired samples allowed the design to attribute the changes in the dependent variables to the independent variable (O'Connell et al., 2017). A paired sample is where the outcome is measured in the same individuals before and after the exposure to the independent variable. The pre and posttest research design allowed the use of paired sample *t*-test to determine whether the exposure to the independent variable may result in statistically significant effects (Laerd Statistics, 2017; O'Connell et al., 2017). The pre and post-test research design was appropriate for the determination of whether there was a significant baseline and post injury difference (s) in reaction time and verbal working memory among NCAA collegiate female student-athlete soccer players after experiencing a head injury.

In this study, no manipulations of conditions were conducted during the research but instead, the changes in the highlighted neurocognitive functions following exposure to head injury was based on the recorded data. It is also important to note that pre and posttest research design allowed the use of archival data in the determination of the relationship between the variables. As noted by Fraenkel and Wallen (2008), the utilization of archival data was described as an expeditious and cost-effective approach to the collection of data.

In this pre and posttest design study, the unit of analysis was the NCAA collegiate female student-athlete soccer players. The individual collegiate female players were the units of observation since the data reaction times, verbal working memory deficits, and age were collected from the individual players who participated in baseline and post ImPACT testing.

Methodology

Population and Sample Selection

Population and sample selection are important steps in quantitative research since the investigators need to recruit members of a population who are representative of the study population. The general population of interest for this study were the NCAA female student soccer athletes. The population was chosen since it was relevant to the research and important in answering the research questions. The population included NCAA female soccer athletes who took baseline and post ImPACT testing. The stated targeted population was appropriate for this study since the data collected by the ImPACT application included the reaction time and verbal working memory deficit of the athletes before and after suffering a head injury (Covassin et al., 2012). The population of interest were selected from a total of 939 individuals who took ImPACT. Soccer athletes made up of 17.9% of the population while the female athletes made up 38.6 % of the individuals who took ImPACT between 2009 to 2011.

The study sample was obtained from the target population. The sample consisted of 33 NCAA collegiate female student soccer athletes who took baseline and post ImPACT between 2009-2011. For this study, only collegiate female soccer athletes were selected. The selection of the college female athlete was received from secondary data on the athletes' level of participation and those who participated in collegiate level soccer games were considered. Therefore, the sample only consisted of college female soccer athletes. Female soccer athletes at the collegiate level represented 3.5% of the larger population of the dataset, where overall female soccer athletes were at 12.6%. The study used all eligible participants from the archival ImPACT database from a private concussion researcher who received datasets from the ImPACT database. The private researcher approved for his dataset to be used for my study.

The sample size was determined by reviewing the literature and via a power analysis using G*Power analysis by G*Power software 3.1.9.4, downloaded from their website (www.gpower.hhu.de/en.html)/(Faul et al., 2007; Faul et al., 2009). An alpha error of 0.05, a medium effect size, and statistical power of 0.80, was used for calculating the estimated sample size of 64 in each sample group.

Archival Data

This study explored archival data generated from an ImPACT dataset. The dataset presented the data in both numerical and non-numeral format. The data were first filtered based upon gender, where only female participants were selected. The selection was carried out using the SPSS data selection option. The data were filtered based on the sport the participants were engaged in where only those who participated in soccer were selected. The data were further selected based on the level of participation where only the participants who took part in the collegiate level of soccer games were selected. After the data filtering, data on the age of the participants were recoded to categorical data with two age groups (17–19 years and 20–22 years). The recoding of data was carried out using the SPSS data transformation option where data were recoded to a new variable while retaining the existing age dataset scored on a continuous scale. The verbal working memory score was based on the verbal memory composite values (User Memory Composite Score Verbal, VMCS) provided in the database. The values were composites of the assessment of the attentional processes, learning, and memory within the verbal domain. The VMCS is an average score of three scores (Word memory total percent correct, Symbol match: total correct hidden/9*100, and Three letters: percent total letters correct). The VMCS was scored in percentage (0–100%). The reaction time score was based on reaction time composite (userReactionTimeCompositeScore, RTCS) that was also computed and provided in the database. The score determined the average response speed. The RTCS was an average score of three scores (Average correct RT of interference stage of X's and O's, Symbol match: average correct RTvisible /3, and Color match: average correct RT). The VMCS was scored as a continuous scale.

Descriptive statistics were provided as a summary of the data of the variables of the study. Descriptive statistics such as means and the standard deviation were calculated to describe participants' age, RTCS, and VMCS. The mean RTCS and VMCS between the age groups were also computed. Minimum and maximum values were also calculated to determine the range and description of the data spread.

The data that were used in this study was previously collected data, which have been stored in the ImPACT database www.impactconcussion.com. ImPACT's baseline testing was used to document the functioning of the healthy brain prior to sustaining a concussion and it was administered at the beginning of the sporting season. ImPACT post injury neurocognitive tests were used to understand the status of an athlete's injury in relation to cognitive activity and it was administered to the athletes who suffered a brain injury. The ImPACT is easy to do a test, which takes only 20 minutes and only needs one to have a laptop with an internet connection (Elbin et al., 2019). Qualified healthcare practitioners, certified athletic trainers, or team physicians are mandated to administer post injury ImPACT tests (Elbin et al., 2019). Before being uploaded to the servers, the data were de-identified to ensure study participants were not identified.

Site approval for this proposed study was not necessary as the data for this research was archival and secondary. Data were collected from the ImPACT database (www.impactconcussion.com). Therefore, the only permission that was approved was by Walden University's Institutional Review Board (IRB). The first step in the collection of the archival data from the ImPACT database was involving a private researching to release a dataset with the submission of required documentation through the Dissertation Chair. After getting the approval, the archival ImPACT database that was received was searched with the aim of identifying and downloading an updated version of the data. Since the ImPACT database de-identifies all data relating to the identification of participants, the received database had de-identified data and avoided disclosure. Actions taken to protect the data was maintaining a secured and encrypted laptop, which was only accessible by the researcher. Data files will be maintained for a minimum of 3 years before being deleted from the secured laptop, including any back-up files. Statistical Package for the Social Sciences (SPSS) ver. 25 was used in the examination of the collected data.

Instrumentation

Data were collected using the Immediate Post Concussion Assessment and Cognitive Testing ImPACT (Iverrson, 2005), which is a scientifically validated computerized neuropsychological testing tool that is widely used as a gold standard test in the assessment and management of a concussion (Crook, 2018). The tool is FDA approved and it is used in schools, healthcare organizations, and sports organizations to assess and manage a concussion (McCrory et al., 2017). There are three main sections that make up the ImPACT tool with one of them being the section of demographics and the health history information. The second part is made up of a questionnaire that has 22 questions. The third section is made up of six test modules that assess the reaction time, visual memory, processing speed, and verbal working memory (Mayers & Redick, 2012).

The data from the ImPACT tests enables the sports administrators to decide on the safety of the concussed individuals, especially to decide when the concussed individual should return to active sport (Mayers & Redick, 2012).

The ImPACT tool scores gender as either male or female. The education level is scored from 0 to 16. The tool also has a question, which requires the participants to indicate their current sports activity. The tool also has a question that requires the athletes to choose the level of participation from four options (collegiate, high school, and junior). The age of the participants is a score on a continuous scale where the participants fill their age in years. The tool documents the verbal working memory and the reaction time scores for baseline and after the injury on a continuous scale.

Validity

The ImPACT tool offers an instrument that has high generalizability (Covassin et al., 2012). External generalizability of ImPACT is evident by the fact that it is used by more than 1,616 athletes in 779 high schools in the US (Covassin et al., 2012). Therefore, the data that is collected using the ImPACT tool is highly representative of the survey population. The generalizability of the ImPACT tool is also linked to the fact the tool does not discriminate participants based on gender or ethnicity (Covassin et al., 2012). However, it should be noted there is a lack of evidence regarding the ImPACT's internal validity. Only one instrument was used in this study, therefore there were no threats to internal validity as the respondents being influenced by the experience of responding to multiple instruments.

Reliability

According to Iverson et al. (2003), the ImPACT tool is a reliable tool with high test-retest reliabilities of significance between Pearson's r=.65 and r=.86. However, Broglio et al. (2017) reported unacceptably low correlation values at r=.20 and r=.40. Schatz (2010) also reported low to moderate correlation values at r=.30 and r=.60. The reported varying reliabilities could be associated with differences in the population sample size and duration between tests. Iverson et al. (2003) considered 56 healthy controls and testing was done 113 days apart, while Broglio et al.'s (2017) tests were done 45 days apart and included 23,533 student-athletes and military service academy students. Schatz's (2010) duration between tests were two years apart and included 95 collegiate varsity athletes. Given the reported contradictory results associated with the reliability of the ImPACT tool in the previous studies, reliability measurements of my study were calculated by using Cronbach's alpha.

Operational Definition

The independent variables represented participant score at baseline and post injury. The independent variable was considered reliable as post injury scores deteriorated inconsistently when compared with baseline scores for the participants under study. The dependent variables – verbal working memory and reaction times were prevalent while measuring neurocognitive functions (McInnes et al., 2017). Thus, they were reliably used as markers of neurocognitive functions. Additionally, the dependent variables of verbal working memory and reaction time scores were taken from the ImPACT dataset alone, to ensure the nature of measurement would not change, thereby negating any changes in the reliability of measurement. Moreover, the verbal working memory and reaction times indicated high degrees of sensitivity, as exhibited by changes in baseline and post injury values for both markers.

Data Analysis Plan

The Statistical Package for the Social Sciences (SPSS) ver. 26 will be used in the examination of the collected data. The reliability of the instrument was checked using the SPSS reliability analysis command. The reliability analysis for the RTCS in measuring reaction time included all the three scores used in developing the score and the same approach was used to compute the reliability of the VMCS in measuring verbal working memory. A reliability coefficient of 0.70 or higher was considered acceptable as past research reported a Cronbach's alpha coefficient between α=.65 and α=.86 (Lovell & Collins, 2003; Mayers & Redick, 2012). The reliability analysis was conducted by using the following commands in SPSS:

userMemoryCompositeScoreVerbal_1 & userMemoryCompositeScoreVerbal_3.

userReactionTimeCompositeScore_1 & userReactionTimeCompositeScore_3.

The results of the reliability analysis for verbal working memory and reaction scores indicated *a*=.523 and *a*=.627, respectively. Accordingly, the scores were considered sufficiently reliable for testing, given the small sample size of the study.

The next step was the identification of any missing data, data screening and removal of outliers to begin the data analysis of the following research questions and respective hypotheses:

RQ_1: Based on executive functioning factors of the theory of mind, are there significant baseline and post injury differences in reaction time between NCAA collegiate female student-athlete soccer players after experiencing a head injury?

H_01: There are no significant differences in reaction times among NCAA collegiate female student-athlete soccer players after experiencing a head injury.

H_1: There are significant differences in reaction times among NCAA collegiate female student-athlete soccer players after experiencing a head injury.

RQ_2: Based on the executive functioning of the theory of mind, are there significant baseline and post injury differences in verbal working memory deficits between NCAA collegiate female student-athlete soccer players after experiencing a head injury?

H_02: There are no significant differences in verbal working memory among NCAA collegiate female student-athlete soccer players after experiencing a head injury.

H_2: There are significant differences in verbal working memory among NCAA collegiate female student-athlete soccer players after experiencing a head injury.

RQ_3: Based on executive functioning factors of the theory of mind, are there significant baseline and post injury differences in reaction time when comparing age groups between NCAA collegiate female student-athlete soccer players after experiencing a head injury?

H_03: There are no significant differences between baseline and post injury in reaction times when comparing age groups between NCAA collegiate female student-athlete soccer players after experiencing a head injury.

H_3: There are no significant differences between baseline and post injury in reaction times when comparing age groups between NCAA collegiate female student-athlete soccer players after experiencing a head injury.

RQ_4: Based on executive functioning of the theory of mind, are there significant baseline and post injury differences in verbal working memory deficits when comparing age groups between NCAA collegiate female student-athlete soccer players after experiencing a head injury?

H_04: There are no significant differences between baseline and post injury in verbal working memory when comparing age groups between NCAA collegiate female student-athlete soccer players after experiencing a head injury.

H_4: There are significant differences between baseline and post injury in verbal working memory when comparing age groups between NCAA collegiate female student-athlete soccer players after experiencing a head injury.

The paired sample *t* test was the data analysis approach used for research question 1. Before conducting the analysis, assumptions for the data were tested (Laerd Statistics, 2017). The assumptions for paired sample *t* test were as follows; one dependent variable must be scored in continuous scale and dichotomous independent variable. The other assumption was that there should be no significant outliers in the differences between the two related groups. Outliers were assessed using boxplots. The other assumption was the need for the normally distributed distribution of the differences in the dependent variable between the two related groups, which was tested using the Shapiro-Wilk test of normality and a Wilcoxon Signed Rank test.

The Wilcoxon Signed-Rank test was the data analysis approach used for research question 2. Before conducting the analysis, assumptions for the data were tested (Laerd Statistics, 2017). The assumptions for Wilcoxon Signed-Rank test were as follows; one dependent variable must be scored in continuous scale and dichotomous independent variable. The other assumption was the need for a symmetrical distribution of the differences in the dependent variable between the two related groups, which were tested using boxplots.

The data analysis approach used for research question 3 and 4 were independent sample *t* tests. The use of the statistical approach was determined of whether the age (scored in dichotomous scale; 17–19 years and 20–22 years) and the presence of injury (scored in dichotomous scale; baseline and post injury) would interact in explaining reaction times (RQ 3) and verbal working memory deficits (RQ 4). The assumptions for independent sample *t* tests in (RQ 3) and (RQ 4) included the fact that the dependent variables (reaction times and verbal working memory) were scored on a continuous scale and differences within factors (age and presence of injury) consisted of two levels. The residuals that were generated when running the independent sample *t* tests were used to test the presence of outliers. Any values that were greater than ±3 indicated the presence of outliers. A Shapiro-Wilk test of normality was used to test the normality assumption and the significance level of more than 0.05 indicated the presence of a normal distribution. The Levene’s test for equality of variances was tested to determine whether the variance between variable groups were equal. The Levene’s test for equality variances resulted with a significance level of more than 0.05 indicated that the assumption was met. In the case of outliers, the data were recalculated with and without outliers. For RQ3, there were no significant differences in either cases. However, as the results differed for RQ4, a non-parametric Mann-Whitney U test was used instead.

For all statistical tests, the alpha level was set at .05. Findings with $p < .05$ were considered significant and therefore the null hypothesis was rejected. However, the findings of the study that failed to reject the hypothesis if $p \geq .05$, were considered not statistically significant.

Threats to Validity

Even though the data were taken from the same database and the dependent variable were investigated using the same instruments, it is possible that the data collection may have been affected by external or internal factors. It is possible that the database did not account for other events or treatments that could have affected the difference in baseline and post injury scores. Additionally, as data was collected over periods of time, it is possible that it may have been affected by changes in participant responses due to fatigue, medication, changes in nutrition, etc. Moreover, it is possible that these changes could be exaggerated or aggravated due to pre-existing conditions of the participants that were unaccounted for before testing post injury scores. It is also possible that the participants were subconsciously cued to expect their scores to be lesser post injury and thus performed to these expectations. On the other hand, the knowledge of a baseline vs post injury test could have made the participants aware of the nature of the experiment and hence made them try to perform better than they normally would have, had they known that the data would not be used for a study.

Ethical Considerations

One of the important aspects of research ethics is seeking consent from the participants. However, for this study, consent was not necessary as the data had already been obtained from study participants and the data files from the ImPACT test are available and open to the public for research and use (Crook, 2018; Mayers & Redick, 2012). However, the data for this research was obtained from a private researcher and I agreed to respect each person in research by upholding the anonymity rule and protection of each individual identity (Miracle, 2016). Ethical issues related to participants' identity were limited since de-identified archival data were used. Further steps were taken, when necessary, to ensure protection of participants' identifiable data. However, there were no cases of mistaken identifiable data, therefore, no such data needed to be transferred out or deleted from the source file.

This study also adhered to the principle of justice, which required the distribution of the burdens and the benefits (Miracle, 2016). I focused on the principle of justice by ensuring that any respondent wanting access to this study, will have the right to the produced research (Fairfield & Shtein, 2014). Since the research used private data, I ensured that respondents and the public get access to the outcome and findings by disseminating using means that the public can easily access. I plan to disseminate the findings on my study in public domains such as public libraries and share results to the private researcher that provided the ImPACT data for my study. The findings of this study will also be available to scholars and interested parties through publication in relevant online databases and journals.

The other ethical principle that I adhered to was honesty. I upheld honest reporting during data processing, analysis, and presentation. Data fidelity was upheld by ensuring no erroneous and malicious manipulation of the data occurred. Appropriate statistical tests were used to ensure correct analysis and conclusions were made.

The protection of data in research is an important ethical consideration (Miracle, 2016). I ensured that the data from the ImPACT dataset are safely stored and accessible for this study. The data have been stored on my encrypted laptop for secure protection. To ensure data security, the data processing steps such as the reconfiguration process, coding, and actual analysis were completed for this study. If necessary, the data will be maintained for three years after which I will permanently delete the data from my laptop.

Timeline

The study took approximately 3– 4 months to complete. Two months were spent on proposal development and IRB approval. Data analysis, writing of results and oral defense increased the timeline to an additional 4 months.

Summary

This chapter provided an elaborate discussion of the research method used to gather data and answer the research questions. The chapter indicated that the retrospective archival research approach based on pre and posttest research design was based suited to address the research questions and hypotheses. The adoption of the pre and posttest research design was appropriate for the determination of whether there were significant baseline and post injury difference in reaction time and verbal working memory among NCAA collegiate female student-athlete soccer players after experiencing a head injury. The unit of analysis were NCAA collegiate female student athlete soccer players. The individual collegiate female players were units of observation since the data reaction times, verbal working memory deficits, and age were collected from the individual players who participated in baseline and post ImPACT testing. The use of paired sample *t* tests facilitated the assessment of baseline and post injury differences in reaction time and verbal working memory while independent sample *t* tests were determined of whether the age and the presence of injury interacted in explaining reaction times and verbal working memory deficits. The study targeted all eligible participants from the secondary archival ImPACT database. Before analysis of data, I received ethical approval by the dissertation chair and Walden University's IRB committee 12-16-20-0240328. The collection and processing of data adhered to relevant ethical considerations, with the emphasis being placed on data protection and honesty in the processing of data.

Chapter 4: Results

Introduction

This study addressed concussion history and neurocognitive performance, specifically, reaction time and verbal memory among 33 NCAA collegiate female soccer athletes (Covassin et al., 2012). The purpose of this study was to explore and address the association between TBI experiences among collegiate female soccer athletes and neurocognitive deficits of reaction time and verbal working memory. This study's method was quantitative research and I used archival data to examine the effect of head injuries on reaction time and verbal working memory. This chapter described the findings and data analysis. First, the problem statement, research questions, and hypotheses were presented. The validity and the summary of the statistical characteristics were also presented.

The problem that the study addressed related to the neurocognitive deficits experienced by concussed collegiate female soccer athletes. Evidence has shown that individuals who suffer repeated TBIs have the risk of developing long-term neurocognitive deficits such as a decline in reaction time and verbal memory, which could be detrimental to the learning process among students and overall quality of life (Covassin et al., 2008). According to Jorgensen et al. (2018), TBIs have become of increased concern over the last decade, in part due to sport-related traumatic brain injuries. Researchers have shown that TBIs were prevalent in organized collegiate athletics (Galetta, et al., 2015; Olson, 2014; Putukian et al., 2015). Researchers observed that in organized collegiate athletics, sport related TBIs were assessed through comprehensive TBI protocols, such as the ImPACT baseline and post injury TBI evaluation, to collect and assess injuries and cognitive domains (Broglio et al. 2017; Bruce & Echemendia, 2009). Such data have shown a gender disparity of TBIs among female student-athletes (Covassin et al., 2018). According to Hu et al. (2015), soccer players have the highest rate of TBIs in all women's NCAA sports. Female soccer players have significantly higher TBI rates than males (Maher et al., 2014). As the current literature paints a shallow perspective towards at-risk collegiate female TBI impairments and comparisons, due to a lack of female studies and small samples (Covassin et al., 2018). Cognitive deficit symptoms continue to exist even after 10 days following a TBI, as well as these athletes are also susceptible to experience long term sequelae associated with post-TBI symptoms (Covassin et al., 2008). This is problematic as collegiate women's athletics lack studies that focus on TBI injury data, which may pose potentially dangerous problems of unknown injuries, impairments, and neurocognitive deficits.

The purpose of this quantitative study was to explore the literature gap regarding the association between concussion history and neurocognitive testing results of verbal memory and reaction time in female collegiate soccer athletes. The following were the research questions and hypotheses of the research study:

RQ: Based on executive functioning factors of the theory of mind, are there significant baseline and post injury differences in reaction time between NCAA collegiate female student-athlete soccer players after experiencing a head injury?

$H_0$1-There are no significant differences in reaction times among NCAA collegiate female student-athlete soccer players after experiencing a head injury.

H_1-There are significant differences in reaction times among NCAA collegiate female student-athlete soccer players after experiencing a head injury.

RQ_2: Based on the executive functioning of the theory of mind, are there significant baseline and post injury differences in verbal working memory deficits between NCAA collegiate female student-athlete soccer players after experiencing a head injury?

$H_0$2-There are no significant differences in verbal working memory among NCAA collegiate female student-athlete soccer players after experiencing a head injury.

H_2 -There are significant differences in verbal working memory among NCAA collegiate female student-athlete soccer players after experiencing a head injury.

RQ_3: Based on executive functioning factors of the theory of mind, are there significant baseline and post injury differences in reaction time when comparing age groups between NCAA collegiate female student-athlete soccer players after experiencing a head injury?

$H_0$3-There are no significant differences between baseline and post injury in reaction times when comparing age groups between NCAA collegiate female student-athlete soccer players after experiencing a head injury.

H_3-There are significant differences between baseline and post injury in reaction times when comparing age groups between NCAA collegiate female student-athlete soccer players after experiencing a head injury.

RQ4: Based on executive functioning of the theory of mind, are there significant baseline and post injury differences in verbal working memory deficits when comparing age groups between NCAA collegiate female student-athlete soccer players after experiencing a head injury?

$H_0$4 -There are no significant differences between baseline and post injury in verbal working memory when comparing age groups between NCAA collegiate female student-athlete soccer players after experiencing a head injury.

H_4 -There are significant differences between baseline and post injury in verbal working memory when comparing age groups between NCAA collegiate female student-athlete soccer players after experiencing a head injury.

Data Collection

Data Collection Process

The time frame of data collection as well as response rates were within a 14-year period (1997–2011). The data obtained was from a large ImPACT database of 939 de-identified male and female junior high, high school and collegiate athletes, and nationally representative of female and male collegiate athletes who sustained a concussion requiring 2+ post-concussion assessments**.** The sample consisted of the following variables: (a) subject number, (b) gender, (c) handedness, (d) age when ImPACT tested, (e) height, (f) weight, (g) country, (h) first language, (i) second language, (j) education level, (k) special education, (l) current sport, (m) player position, (n) level of participation, (o) years playing, (p) number of concussions, (q) concussion history, (r) treatment received, (s) user ImPACT test type (baseline), (t) user ImPACT test components (verbal working memory score, visual memory score, visual/motor score, reaction time score, impulse control score, word memory score, symbol match score, color match score, three letter sequence, (u) medications (v) ImPACT test type 2 (concussion injury 1), (w) ImPACT test components type 2, (x) ImPACT test type 3 (concussion injury 2), (y) ImPACT test components type 3, (z) symptoms. A checklist (Appendix A) of filter selection process of collegiate female soccer athletes, concussion history, number of concussions, level of participation, user ImPACT test type and components (verbal memory score and reaction time score) occurred to represent the sample of my study. The data filter encompassed a sample of 33 de-identified female collegiate soccer athletes from (2009–2011) that fit the variables of this study. As described in Chapter 3, a power analysis estimated the sample and medium effect size of 64 subjects per sample group. A discrepancy of a lower sample than originally proposed may have contributed to concussion symptoms not being reported by female soccer athletes, missing data, more high school data than college, and possible data integrity from using a secondary database. The lack of fewer NCAA female soccer athletes in concussion research plays a vital role in medium and large effect size samples (Macdonald et al., 2016).

The data collection process was previously collected between 1997–2011 and has been stored in the ImPACT database. A private secondary source retrieved a de-identified ImPACT dataset, and I was given the dataset for my study. Missing data were removed and not included in statistical analysis. Possible errors from receiving data from a secondary source was discussed in chapter 3, threats of validity, however, there were no errors of exposed identity.

The database presented the data on the level of participation and gender in non-numeral format. To facilitate further data processing, the data were assigned numerical codes using the SPSS version 25 transformation command where the data were recoded into different variables. For the case of the level of participation, the collegiate option was assigned code “1” while high school options were assigned code “0.” The commands were “recode” and “variable labels.” For the case of gender, the females were assigned code “1” while male responses were assigned code “0.”

Data Reduction Process

The data reduction process involved the removal/filtering out of the data that were not needed from the dataset. Based on the study’s research questions, the research was interested in NCAA collegiate female student-athlete soccer players with experiences of TBI. The data reduction process was carried out using the SPSS “select cases” command. The first step was the filtering of data based upon gender, where only female participants were selected. The commands used were provided below:

COMPUTE

VARIABLE LABELS

VALUE LABELS

FORMATS

FILTER BY

The data was also filtered based on the sport the participants were engaged in where only those who participated in soccer were selected by the same commands. The data were further filtered based on the level of participation where only the participants who took part in the collegiate level of soccer games were selected. For this step, the numerically coded data ('collegiate') were considered. The data were also filtered based on gender where only the female participants were selected. For this step, the numerically coded data ('gendersrt') were considered.

Data on age, which were presented in continuous scale were transformed into categorical by recoding into two age groups (17–19 years and 20–22 years). The dataset did not represent any age group from 22–24, which was planned in chapter 3. The recoding was carried out using the SPSS data transformation option where data was recoded to a new variable while retaining the existing age dataset scored on a continuous scale. The recoding process involved the assigning of code "1" to ages 17 to 19 and code "2" to ages 20 to 22. The commands used were RECODE userAgeWhenTested (17 thru 19=1) and RECODE userAgeWhenTested (20 thru 22=2).

Descriptive and Demographic Characteristics of Sample

The dataset encompassed 939 junior high, high school and collegiate subjects. The flowchart presented in Figure 1 represents the demographic characteristics of the dataset of the following measurements. The dataset that I received contained 362 female athletes and 577 male athletes, reflecting the following data: (a) 101 collegiate female athletes, (b) 231 high school female athletes, (c) 19 junior high female athletes, (d) 11 missing data for female athletes, (e) 65 collegiate male athletes, (f) 464 high school male athletes, (g) 34 junior high school male athletes, and (h) 14 missing data for male athletes.

The flowchart presented in Figure 2 represents all female collegiate soccer athletes filtered by female gender, ages 17 thru 22, soccer sport, concussion history, and ImPACT verbal working memory and reaction time composite values, which resulted in (*n*=33) valid subjects for the variables for this study. The athlete's playing position among the 33 subjects with sustained concussions were (1) right-wing forward, (1) outside midfielder, (1) midfield forward, (4) midfield, (1) keeper, (1) junior, (5) goalkeeper, (4) forward, (12) defenders, and (1) center midfielder.

Figure 1

Flowchart of Secondary De-Identified ImPACT Dataset

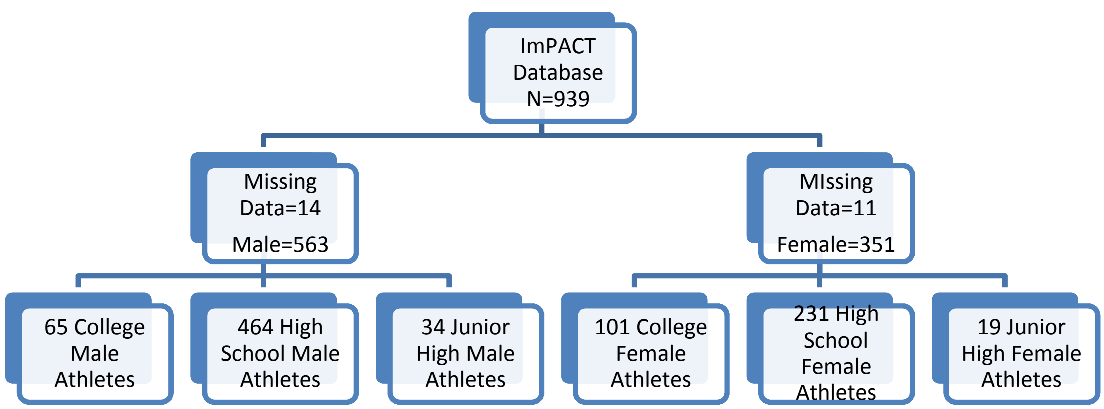
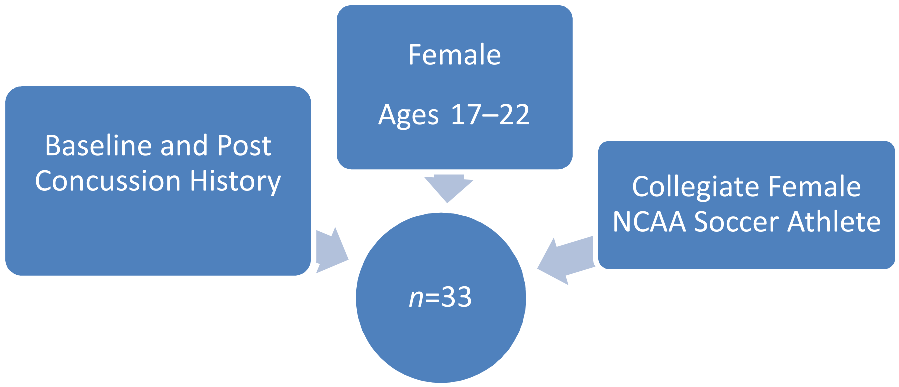


Figure 2

Flowchart of Compiled Filtered ImPACT Data Sample of 101 College Female Athletes' Verbal Working Memory and Reaction Time Scores Between 2009–2011



This sample is a small representation of the larger population of interest as 50,000 cases of concussed soccer players are affected by TBI every year (O'Kane et al., 2014). This small sample size was of convenience by accepting a secondary de-identified dataset that I was able to filter to answer my research questions. The results of the study may be generalized to collegiate female soccer athletes in the United States but review with caution since the sample size was less than expected. The findings presented in Table 4.1 show the means of the verbal memory composite values (User Memory Composite Score Verbal, VMCS) and the reaction time composite (user Reaction Time Composite Score, RTCS) at the baseline. The findings indicated that from a total of 33 participants who took part in the study, 21 of them were aged between 17 and 19 years while 12 were aged between 20 and 22 years. Among those aged 17 and 19 years their mean (*SD*) verbal memory composite score was 88.19 (± 9.411) while for the participants aged between 20 and 22 years the mean (*SD*) verbal memory composite score was 90.08 (± 6.626). Table 1 also indicates the mean reaction time composite score for the participants aged 17 and 19 years was .56 (± .06557) while the participants aged between 20 and 22 years had a mean score of .565 (± .07217).

Table 1

Descriptive Statistics

	Aged 17–19 years (n = 21)		Aged 20–22 years (n = 12)	
	M	*SD*	*M*	*SD*
Memory composite score verbal	88.19	± 9.411	90.08	± 6.626
Reaction time composite score	.5600	± .06557	.5650	± .07217

Results

Research Question 1

RQ_1: Based on executive functioning factors of the theory of mind, are there significant baseline and post injury differences in reaction time between NCAA collegiate female student-athlete soccer players after experiencing a head injury?

$H_0$1-There are no significant differences in reaction times among NCAA collegiate female student-athlete soccer players after experiencing a head injury.

H_1-There are significant differences in reaction times among NCAA collegiate female student-athlete soccer players after experiencing a head injury.

A paired sample *t* test was carried out to determine whether there were significant baseline and post injury differences in reaction time between NCAA collegiate female student-athlete soccer players after experiencing a head injury. There are four assumptions that need to be met for a paired sample *t* test. Each of the assumptions are identified, tested and the outcomes are provided below.

1. One dependent variable that is measured at the continuous. Based on the adopted research design the dependent variable (reaction time) was measured at the continuous scale.
2. One independent variable that is dichotomous: Based on the research design, the independent variable was the presence of concussion and was consisted two categorical, related groups (participants before and after concussion).
3. No significant outliers in the differences between the two related groups: This assumption was tested by determining whether there were unusual reaction time values baseline and post injury using boxplots. The inspection of the boxplot showed no outliers (see Appendix B-Boxplot B1).
4. The need for normally distribution in the distribution of the differences in the dependent variable between the two related groups. This assumption was tested using Shapiro-Wilk test of normality. As shown in Table 2, the Sig. value under the Shapiro-Wilk column is greater than 0.05, to conclude that "Diff_In_Reac_Scores" for this subset of individuals are normally distributed.

Table 2

Normality Outcome for Difference in Reaction Scores (RQ1)

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Diff_In_Reac_Scores	0.102	33	.200*	0.975	33	0.639

The descriptive outcome showed that mean reaction time composite score after experiencing a head injury was lower (0.5285, *SD* = 0.04823), compared to the score before head injury (0.5618, *SD* = 0.06696; Table 3).

Table 3

Means of Baseline and Post injury Reaction Time Among NCAA Collegiate Female Student-Athlete Soccer Players for RQ1

		M	*n*	*SD*	SEm
Pair	userReactionTimeCompositeScore_1	.5618	33	.06696	.01166
2	userReactionTimeCompositeScore_3	.5285	33	.04823	.00840

Based on the obtained findings, the hypothesis that there are no significant differences in reaction times among NCAA collegiate female student-athlete soccer players after experiencing a head injury was rejected. Therefore, the findings indicated that there are significant differences in reaction times among NCAA collegiate female student-athlete soccer players after experiencing a head injury. As shown in Table 4, the reported difference in the baseline and post injury differences in reaction time was statistically significant ($t(32) = 3.149$, $p = .004$). The effect size of the test was calculated by the formula d=Mean/SD, i.e., $d = 0.0333/0.0608 = 0.55$, which was a moderate effect according to Cohen's *d* classification of effect sizes (Cohen, 1992), where 0.2 is small effect, 0.5 is moderate effect and a value greater than or equal to 0.8 was a strong effect.

Thus, the difference between groups was moderate and as the test shows, statistically significant.

Table 4

Comparison of the Baseline and Post injury Differences in Reaction Time Between NCAA Collegiate Female Student-Athlete Soccer Players (RQ1)

			95% CI				
Mean	*SD*	Std. Error Mean	*LL*	*UL*	*t*	*df*	*P*-value
0.0333	0.0608	0.0106	0.01177	0.05490	3.149	32	0.004

Note: CI=confidence interval; *LL*=lower limit; *UL*=upper limit

Research Question 2

RQ_2: Based on the executive functioning of the theory of mind, are there significant baseline and post injury differences in verbal working memory deficits between NCAA collegiate female student-athlete soccer players after experiencing a head injury?

$H_0 2$-There are no significant differences in verbal working memory among NCAA collegiate female student-athlete soccer players after experiencing a head injury.

H_2 -There are significant differences in verbal working memory among NCAA collegiate female student-athlete soccer players after experiencing a head injury.

There were three assumptions that needed to be met for paired sample *t* test. Each of the assumption was identified, tested and the outcomes are provided below.

1. One dependent variable that is measured at the ordinal or continuous level. Based on the adopted research design the dependent variable (verbal working memory) was measured at the continuous scale.

2. The independent variable should consist of two categorical, "related groups" or "matched pairs". The independent variable is a “matched pair”: i.e., the presence of concussion was measured in participants before and after a concussion.
3. The distribution of the differences between the two groups needed to be symmetrical in shape. The boxplot indicated a high level of symmetry, with the minimum and maximum values being ±25 and, a range of 50, and a median value of 0. (see Appendix B-Boxplot B2).
4. Three significant outliers were detected in the differences between the two related groups. This was tested by determining whether there were unusual reaction time values baseline and post injury using boxplots. While, the outliers did not affect the shape of the distribution, they significantly affected the mean and standard deviation. As this assumption was violated, I could not use the paired sample *t*-test. I also did not remove the outliers as there were no indications of an error in data recording, and the outliers may be of significance that can be explored in further research. Hence, I used the Wilcoxon Signed-Rank Test to check for differences in verbal working memory deficits between NCAA collegiate female student-athlete soccer players after experiencing a head injury.

The descriptive outcome showed the means of verbal working memory composite score before experiencing head injury was lower (*M*=88.88, *SD* = 8.444), as compared to the score after head injury (*M*=89.64, *SD* = 8.325). Additionally, the median verbal working memory composite score before experiencing head injury was higher (91) as compared to the score after head injury (90)/(Table 5).

Table 5

Descriptive Outcome: Means of Baseline and Post injury Verbal Working Memory Deficits Among NCAA Collegiate Female Student-Athlete Soccer Players (RQ2)

		M	*n*	*SD*	Median
Pair	userMemoryCompositeScoreVerbal_1	88.88	33	8.444	91.00
1	userMemoryCompositeScoreVerbal_3	89.64	33	8.325	90.00

As shown in Table 6, compares the verbal working memory deficits among the participants' before (baseline) and after (post) a concussion. I can see from the table's legend that an equal number of participants had a higher pre-concussion score and a lower post-concussion score, with 15 participants each. Three participants had no change in their scores.

Table 6

Ranks Table of Verbal Working Memory Scores (RQ2)

		n	*Mean Rank*	Sum of Ranks
userMemoryCompositeScoreVerbal_3 - userMemoryCompositeScoreVerbal_1	Negative Ranks	15[a]	14.90	223.50
	Positive Ranks	15[b]	16.10	241.50
	Ties	3[c]		
	Total	33		

a. userMemoryCompositeScoreVerbal_3 < userMemoryCompositeScoreVerbal_1
b. userMemoryCompositeScoreVerbal_3 > userMemoryCompositeScoreVerbal_1
c. userMemoryCompositeScoreVerbal_3 = userMemoryCompositeScoreVerbal_1

As shown in Table 7, the reported difference in the baseline and post injury differences in verbal working memory deficits was not statistically significant ($Z = -.185$, $p = .853$). Therefore, based on the obtained findings, the hypothesis that there are no significant differences in verbal working memory deficits among NCAA collegiate female student-athlete soccer players after experiencing a head injury, was accepted. Therefore, the findings indicated that there are no differences in verbal working memory deficits among NCAA collegiate female student-athlete soccer players after experiencing a head injury.

Table 7

Comparison of the Baseline and Post injury Differences in Verbal Working Memory Deficits Between NCAA Collegiate Female Student-Athlete Soccer Players (RQ2)

Statistics	Results
Z	-.185[b]
Asymp. Sig. (2-tailed)	0.853

The effect size of the test was calculated by dividing the absolute test statistic Z by the square root of total number of pairs, i.e., $Z/\sqrt{n} = 0.185/\sqrt{33} = 0.032$, which was a small effect according to Cohen's classification of effect sizes (Cohen, 1992), where 0.2 is small effect, 0.5 is moderate effect and a value greater than or equal to 0.8 is a strong effect. Thus, the difference between groups was small and as the test shows, statistically insignificant.

Research Question 3

RQ_3: Based on executive functioning factors of the theory of mind, are there significant baseline and post injury differences in reaction time when comparing age groups between NCAA collegiate female student-athlete soccer players after experiencing a head injury?

$H_0 3$: There are no significant differences between baseline and post injury in reaction times when comparing age groups between NCAA collegiate female student-athlete soccer players after experiencing a head injury.

H_3: There are significant differences between baseline and post injury in reaction times when comparing age groups between NCAA collegiate female student-athlete soccer players after experiencing a head injury.

An independent sample *t* test was carried out to determine whether there were significant baseline and post injury differences in reaction time when comparing age groups between NCAA collegiate female student-athlete soccer players after experiencing a head injury. There are four assumptions that need to be met for an independent sample *t* test. Each of the assumption are identified, tested and the outcomes are provided below.

1. One dependent variable that was measured at the continuous level. Based on the adopted research design the dependent variable (difference in reaction time) was measured at the continuous scale.

2. One independent variable that was dichotomous: Based on the research design, the independent variable was age, and consisted of two categorical groups (age group 1 = 17–19 years and age group 2 = 20–22).
3. There was one significant outlier in the differences between the two related groups: This assumption was tested by determining whether there were unusual differences in reaction time values within the two age groups. The inspection of the boxplot (see Appendix B-Boxplot B3) showed one significant outlier in the age group 17–19 years of age. As this could be of significance, two tests were conducted, one with the outlier (see Table 10) and one without the outlier (see Table 12).
4. The need for normally distribution in the distribution of the differences in the dependent variable within the two groups. This assumption was tested using Shapiro-Wilk test of normality. As shown in Table 8, the Sig. value under the Shapiro-Wilk column was greater than 0.05, to conclude that "Diff_In_Reac_Scores" for both subsets of individuals were normally distributed.

Table 8

Normality Outcome of Difference in Reaction Scores (RQ3)

		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Age	Statistic	df	Sig.	Statistic	df	Sig.
Diff_In_Reac_Scores	1	0.130	21	.200*	0.948	21	0.317
	2	0.215	12	0.132	0.928	12	0.355

The descriptive outcome for the test conducted with outliers showed that the mean difference in reaction times pre and post injury for the age group 17–19 was higher (-0.0352, *SD* = 0.0564), compared to the age group 20–22 (-0.03, *SD* = 0.0705)/(Table 9).

Table 9

Descriptive Outcome: Means of Difference in Reaction Time Among Different Age Groups of NCAA Collegiate Female Student-Athlete Soccer Players (With Outliers) RQ3

	Age	*N*	*M*	*SD*	SEm
Diff_In_Reac_Scores	1	21	-0.0352	0.0564	0.0123
	2	12	-0.0300	0.0705	0.0203

The Levene's test for equality of variances has a p-value greater than 0.05, hence I used the results of the row "equal variances assumed." As shown in Table 10, the difference in reaction time between age groups was not statistically significant in the data ($t(31) = -.234$, $p = .816$). Thus, based on the obtained findings, the hypothesis that there are no significant differences between baseline and post injury in reaction times when comparing age groups between NCAA collegiate female student-athlete soccer players after experiencing a head injury, was accepted.

Table 10

Comparison of Means of Difference in Reaction Time Between Different Age Groups of NCAA Collegiate Female Student-Athlete Soccer Players (With Outliers) RQ3

		95% CI				
Mean Difference	Std. Error Difference	*LL*	*UL*	*t*	*df*	*P*-value
-.00524	.02234	-.05080	.04032	-.234	31	.816

Note. CI=confidence interval; *LL*=lower limit; *UL*=upper limit

The descriptive outcome for the test conducted without outliers showed that the mean difference in reaction times pre and post injury for the age group 17–19 was lower (-0.028, *SD* = 0.0467), compared to the age group 20–22 (-0.03, *SD* = 0.0705; Table 11).

Table 11

Descriptive Outcome: Means of Difference in Reaction Time Among Different Age Groups of NCAA Collegiate Female Student-Athlete Soccer Players (Without Outliers) RQ3

	Age	*N*	*M*	*SD*	SEm
Diff_In_Reac_Scores	1	20	-0.0280	0.0467	0.0105
	2	12	-0.0300	0.0705	0.0203

The Levene's test for equality of variances has a p-value greater than 0.05, hence I used the results of the row "equal variances assumed." As shown in Table 12, the difference in reaction time between age groups were not statistically significant in the data ($t(16.896) = 0.087$, $p = .931$). Thus, based on the obtained findings, the hypothesis that there are no differences in baseline and post injury reaction times between the two age groups of NCAA collegiate female student-athlete soccer players, without outliers, was accepted.

Table 12

Comparison of Means of Difference in Reaction Time Between Different Age Groups of NCAA Collegiate Female Student-Athlete Soccer Players (Without Outliers) RQ3

		95% CI				
Mean Difference	Std. Error Difference	*LL*	*UL*	*t*	*df*	*P*-value
0.002	0.02287	-0.04627	0.05027	0.087	16.896	0.931

Note. CI=confidence interval; *LL*=lower limit; *UL*=upper limit

The effect size of the test (with outliers) was calculated by using the Hedges's *g* as the sample size is small (21 for one sample and 12 for the other). The effect size was calculated by the formula $M_1 - M_2 / SD^*_{\text{pooled}}$ and is 0.08418. This was a small effect according to Cohen's classification of effect sizes (Cohen, 1992), where 0.2 is small effect, 0.5 is moderate effect and a value greater than or equal to 0.8 is a strong effect. Thus, the difference between groups is small and as the test shows, statistically insignificant.

The effect size of the test (without outliers) was calculated by using the Hedges's *g* as the sample size was small (21 for one sample and 12 for the other). The effect size was calculated by the formula $M_1 - M_2 / SD^*_{\text{pooled}}$ and is 0.0919. This was a small effect according to Cohen's classification of effect sizes (Cohen, 1992), where 0.2 is small effect, 0.5 is moderate effect and a value greater than or equal to 0.8 is a strong effect. Thus, the difference between groups was small and as the test shows, statistically insignificant.

Research Question 4

RQ_4: Based on executive functioning of the theory of mind, are there significant baseline and post injury differences in verbal working memory deficits when comparing age groups between NCAA collegiate female student-athlete soccer players after experiencing a head injury?

H_04: There are no significant differences between baseline and post injury in verbal working memory when comparing age groups between NCAA collegiate female student-athlete soccer players after experiencing a head injury.

H_4: There are significant differences between baseline and post injury in verbal working memory when comparing age groups between NCAA collegiate female student-athlete soccer players after experiencing a head injury.

An independent samples *t*-test was carried out to determine whether there were significant baseline and post injury differences in verbal working memory deficits when comparing age groups between NCAA collegiate female student-athlete soccer players after experiencing a head injury. There are four assumptions that need to be met for an independent sample *t*-test. Each of the assumption was identified, tested and the outcomes are provided below.

1. One dependent variable that is measured at the continuous level. Based on the adopted research design the dependent variable (difference in verbal memory scores) was measured at the continuous scale.
2. One independent variable that is dichotomous: Based on the research design, the independent variable was age, and of consisted two categorical groups (age group 1 = 17–19 years and age group 2 = 20–22).
3. There was one significant outlier in the differences between the two related groups: This assumption was tested by determining whether there were unusual differences in verbal memory scores within the two age groups. The inspection of the boxplot (see Appendix B-Boxplot B4) showed one significant outlier in the age group 17–19 years of age. As this could be of significance, two tests were conducted, one with the outlier (Table 15) and one without the outlier (Table 17).

4. The need for normally distribution in the distribution of the differences in the dependent variable within the two groups. This assumption was tested using Shapiro-Wilk test of normality. As shown in Table 13, the Sig. value under the Shapiro-Wilk column is greater than 0.05, we can conclude that "Diff_In_VerbalMem_Scores" for both subsets of individuals were normally distributed.

Table 13

Normality Outcome of Verbal Working Memory Scores (RQ4)

		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Age	Statistic	*df*	Sig.	Statistic	*df*	Sig.
Diff_In_VerbalMem_Scores	1	0.131	21	.200*	0.954	21	0.405
	2	0.104	12	.200*	0.967	12	0.875

The descriptive outcome for the test conducted with outliers showed that more members in the age group 17–19 had higher verbal memory working scores post injury (*M*=2.9048, *SD* = 10.995), as compared to the age group 20–22 (*M*-3, *SD* = 4.5126; Table 14).

Table 14

Descriptive Outcome: Means of Difference in Verbal Working Memory Deficits Different Age Groups of NCAA Collegiate Female Student-Athlete Soccer Players (With Outlier) RQ4

	Age	*N*	*M*	*SD*	SEm
Diff_In_VerbalMem_Scores	1	21	2.9048	10.9950	2.3993
	2	12	-3.0000	4.5126	1.3027

The Levene's test for equality of variances had a p-value greater than 0.05, hence I used the results of the row "equal variances assumed." As shown in Table 15, the difference in verbal working memory between age groups were not statistically significant in the data with outlier (*t*(31) = 1.768, *p* = .087). Thus, based on the obtained finding, the hypothesis that there are no significant differences between baseline and post injury in verbal working memory when comparing age groups between NCAA collegiate female student-athlete soccer players after experiencing a head injury, was accepted.

Table 15

Comparison of Means of Difference in Verbal Memory Scores Between Different Age Groups of NCAA Collegiate Female Student-Athlete Soccer Players (With Outlier) RQ4

		95% CI				
Mean Difference	Std. Error Difference	*LL*	*UL*	*t*	*df*	*P*-value
5.9048	3.3406	-.90847	12.71799	1.768	31	.087

Note. CI=confidence interval; *LL*=lower limit; *UL*=upper limit

The descriptive outcome for the test conducted with outliers showed that more members in the age group 17–19 had higher verbal memory working scores post injury (4.3, *SD* = 9.1772), as compared to the age group 20–22 (-3, *SD* = 4.5126; Table 16).

Table 16

Means of Difference in Verbal Working Memory Deficits Different Age Groups of NCAA Collegiate Female Student-Athlete Soccer Players (Without Outlier) RQ4

	Age	*N*	*Mean*	SD	SEm
Diff_In_VerbalMem_Scores	1	20	4.3000	9.1772	2.0521
	2	12	-3.0000	4.5126	1.3027

The Levene's test for equality of variances had a p-value less than 0.05, hence I used the results of the row "equal variances not assumed." As shown in Table 17, the difference in verbal working memory between age groups was statistically significant in the data without outlier (t(30) = 2.564, p = .016). Thus, based on the obtained finding, the hypothesis that there are no significant differences in baseline and post-head injury verbal working memory scores between different age groups of NCAA collegiate female student-athlete soccer players, was rejected. Hence, there are significant differences in verbal working memory among NCAA collegiate female student-athlete soccer players after experiencing a head injury when the outlier is removed.

Table 17

Comparison of Means of Difference in Verbal Memory Scores Between Different Age Groups of NCAA Collegiate Female Student-Athlete Soccer Players(Without Outlier) RQ4

		95% CI				
Mean Difference	Std. Error Difference	*LL*	*UL*	*t*	*df*	*P*-value
7.3000	2.8474	1.4849	13.1151	2.564	30	.016

Note. CI=confidence interval; *LL*=lower limit; *UL*=upper limit

As the results with and without outliers do not agree, I conducted a non-parametric Mann-Whitney U-test to analyze whether the difference between baseline and post injury verbal memory scores differ between the age groups. Table 18 indicates that age group 1 (17 – 19 years) had higher differences in pre-and post injury verbal memory scores as compared to the age group 2 (20 – 22 years).

Table 18

Comparison of Ranks of Difference in Verbal Memory Scores Between Different Age Groups of NCAA Collegiate Female Student-Athlete Soccer Players (RQ4)

	Age	N	Mean Rank	Sum of Ranks
Diff_In_VerbalMem_Scores	1	21	19.60	411.50
	2	12	12.46	149.50
	Total	33		

Table 19 shows that it can be concluded that differences in baseline and post injury verbal memory scores were statistically significantly higher in the age group 1 (17–19 years) as compared to age group 2 (20–22 years) with ($U = 71.5$, $p = .04$). As the mean scores are positive in the differences for the age group (17–19 years), it could imply that the verbal memory working scores are less affected in younger age groups as compared to older age groups (20–22 years).

Table 19

Mann-Whitney Test Results (RQ4)

Test Statistics[a]	
	Diff_In_VerbalMem_Scores
Mann-Whitney U	71.500
Wilcoxon W	149.500
Z	-2.043
Asymp. Sig. (2-tailed)	0.041
Exact Sig. [2*(1-tailed Sig.)]	.040

The effect size of the test is calculated by dividing the absolute test statistic Z by the square root of total number of pairs, i.e., $Z/\sqrt{n} = 2.043/\sqrt{33} = 0.356$, which was a small effect according to Cohen's classification of effect sizes (Cohen, 1992), where 0.2 is small effect, 0.5 is moderate effect and a value greater than or equal to 0.8 is a strong effect. Thus, the groups differ strongly from each other, and the difference is statistically significant.

Summary

The research questions and hypotheses were highlighted in this chapter. Then the data collection and data reduction processes were presented. The demographic characteristics and descriptive statistics were described, and calculations were reported. The assumptions of sample *t* tests and solutions to outliers, were fully explained in detail.

A secondary de-identified dataset of junior high, high school, and collegiate level ImPACT data were analyzed and examined to reveal any differences in reaction time and verbal working memory after a concussion. The dataset consisted of 939 cases of male and female athletes that suffered a concussion from 1997–2011. The sample for this study included 33 female collegiate soccer athletes who suffered a concussion from 2009–2011 and fit the required variables. Their ages were from 17–22 years old. The obtained findings to research question 1 and hypothesis was rejected. A paired sample *t*-test revealed that there are significant differences in reaction times among NCAA collegiate female student-athlete soccer players after experiencing a head injury $p < .05$ level, ($t(32) = 3.149$, $p = .004$). The effect size of the test was calculated by the formula d=Mean/*SD*, i.e., $d = 0.0333/0.0608 = 0.55$, which is a moderate effect according to Cohen's classification of effect sizes (Cohen, 1992), where 0.2 is small effect, 0.5 is moderate effect and a value greater than or equal to 0.8 is a strong effect. Thus, the difference between groups was moderate and as the test shows, statistically significant. The null hypothesis was rejected. The analysis of tabulations was presented in Tables 1-4.

Another paired sample *t* test was the initial data analysis for research question 2, however, there were assumptions that were not met. Three significant outliers were detected in the differences between the two related groups. This was tested by determining whether there were unusual reaction time values at baseline and post injury by using boxplots. While, the outliers did not affect the shape of the distribution, they significantly affected the mean and standard deviation. As this assumption was violated, the paired sample *t* test was not calculated. Since there were no indication of an error in data recording, I did not remove the outliers as they may be of significance that can be explored in further research. The Wilcoxon Signed-Rank Test was used to check for differences in verbal working memory deficits between the collegiate female student athlete soccer players. The findings indicated no significant differences in verbal working memory deficits among NCAA collegiate female student-athlete soccer players after experiencing a head injury (Z = -.185, p = 0.853). Therefore, the null hypothesis was accepted.

The effect size was calculated and resulted in $Z/\sqrt{n} = 0.185/\sqrt{33} = 0.032$, which was a small effect size according to Cohen's classification of effect sizes (Cohen 1992), where 0.2 is small effect, 0.5 is moderate effect and a value greater than or equal to 0.8 is a strong effect size. Thus, the difference between groups was small and as the test shows, statistically insignificant.

An independent samples *t*-test was carried out for research question 3 to

determine whether there were significant baseline and post injury differences in reaction time when comparing age groups between NCAA collegiate female student-athlete soccer players after experiencing a head injury, however, there was one assumption that did not meet the criteria for an independent samples *t* test. There was one significant outlier in the differences between the two related groups: This assumption was tested by determining whether there were unusual differences in reaction time values within the two age groups. The inspection of the boxplot showed one significant outlier in the age group 17–19 years of age. As this could be of significance, two tests were conducted, one with the outlier and one without the outlier. The Levene's test for equality of variances was calculated to indicate some significance which included the outlier. The difference in reaction time between age groups was not statistically significant in the data ($t(31) = -.234$, $p = .816$). Thus, the findings show that there are no differences in baseline and post injury reaction times between the two age groups of NCAA collegiate female student-athlete soccer players. The Levene's test for equality of variances without the outlier showed $p > .05$, hence, the difference in baseline and post injury reaction times between age groups were not statistically significant ($t(16.896) = 0.087$, $p = .931$), among NCAA collegiate female student-athlete soccer players. Therefore, the null hypothesis was accepted.

The Hedges's *g* was used to calculate the effect size of the test (with outliers) since the sample size was small (21 for one sample and 12 for the other). The effect size was calculated by the formula $M_1 – M_2 / SD^*_{pooled}$ and is 0.08418. This was a small effect according to Cohen's classification of effect sizes (Cohen, 1992), where 0.2 is small effect, 0.5 is moderate effect and a value greater than or equal to 0.8 is a strong effect. Thus, the difference between groups is small and as the test shows, statistically insignificant.

The effect size of the test (without outliers) was also calculated by using the Hedges's *g* as the sample size was small (21 for one sample and 12 for the other). The effect size was calculated by the formula $M_1 – M_2 / SD^*_{pooled}$ and is 0.0919. This was a small effect according to Cohen's classification of effect sizes (Cohen, 1992), where 0.2

is small effect, 0.5 is moderate effect and a value greater than or equal to 0.8 is a strong effect. Thus, the difference between groups was small and as the test shows, statistically insignificant.

An independent samples *t*-test was used for research question four to determine whether there were significant baseline and post injury differences in verbal working memory deficits when comparing age groups between NCAA collegiate female student-athlete soccer players after experiencing a head injury. There was one significant outlier in the differences between the two related groups: This assumption was tested by determining whether there were unusual differences in verbal memory scores within the two age groups. The inspection of the boxplot showed one significant outlier in the age group 17–19 years of age. Once again, two tests were conducted, one with the outlier and one without the outlier. The Levene's test for equality of variances had a $p > .05$, the difference in verbal working memory between age groups was not statistically significant in the data with an outlier ($t(31) = 1.768$, $p = 0.087$). Thus, the findings show that there were differences in baseline and post injury verbal memory working scores between the two age groups of NCAA collegiate female student-athlete soccer players with the outlier. The second Levene's test for equality of variances had a $p < .05$, the difference in verbal working memory between age groups was statistically significant in the data without the outlier ($t(30) = 2.564$, $p = .016$). Thus, the obtained finding rejected the null hypothesis that there are no significant differences in baseline and post-head injury verbal working memory scores between different age groups of NCAA collegiate female student-athlete soccer players. Therefore, there are significant differences in verbal working memory among NCAA collegiate female student-athlete soccer players after experiencing a head injury when the outlier was removed.

As the results with and without outliers do not agree, a non-parametric Mann-Whitney U-test was conducted to analyze whether the difference between baseline and post injury verbal working memory scores differ between the age groups. The results showed that age group 1 (17–19 years) had higher differences in baseline and post injury verbal working memory scores as compared to the age group 2 (20 –22 years). It can be concluded that differences in baseline and post injury verbal working memory scores were statistically significantly higher in the age group 1 (17–19 years) as compared to age group 2 (20–22 years) with (U = 71.5, $p = .04$). As the mean scores were positive in the differences for the age group (17–19 years), it could imply that the verbal working memory scores were more affected in younger age group as compared to the older age group (20–22 years).

The effect size of the test was calculated by dividing the absolute test statistic Z by the square root of total number of pairs, i.e., $Z/\sqrt{n} = 2.043/\sqrt{33} = 0.356$, which was a small effect according to Cohen's classification of effect sizes (Cohen 1992), where 0.2 is small effect, 0.5 is moderate effect and a value greater than or equal to 0.8 is a strong effect. Thus, the groups differ strongly from each other, and the small sample size could have contributed to the power of each test, however, there were comparison differences as statistically significant.

In the subsequent chapter, the limitations of the study and the interpretation of findings are explained. The recommendations are discussed based on the existing literature with aim of identifying areas of agreement and contradiction, along with the implications of positive social change.

Chapter 5: Discussion, Conclusions, and Recommendations

Introduction

The purpose of this quantitative study was to address the gap pertaining to the impact of concussion history on neurocognitive performance among NCAA collegiate female student soccer athletes, by comparing baseline and post injury scores of reaction time and verbal working memory. Additionally, the research assessed whether age influenced the reaction time and verbal working memory among female NCAA collegiate student soccer athletes who had suffered head injuries. Thus, the research highlights the potential association between head injury and neurocognitive deficits in reaction time and verbal working memory, while also assessing whether age is a significant interaction factor in such an association. The research was quantitative in nature and utilized a retrospective archival research method to extract data. In this study I examined the effect of TBI on two markers of neurocognitive capacity – verbal working memory and reaction time, suggested as two problematic TBI neurocognitive factors in ToM tasks (Honan et al., 2015). The target population was identified as NCAA female collegiate student soccer athletes and the sample was also categorized into two groups on the base of age, 17 to 19 years of age and 20 to 22 years of age. This chapter presents an interpretation of the findings of the study in context of the theoretical model, its implications, recommendations, and conclusions. This chapter also includes the limitations to the study and provided justifications for further research.

Athletes with recurring instances of TBI are at a greater risk of suffering neurocognitive deficits over time, thereby deteriorating the quality of education among students, and reducing overall quality of life in the long-term (Covassin et al., 2008). Past research has indicated that sport related TBIs have increased in organized collegiate athletics (Galetta, et al., 2015; Olson, 2014; Putukian et al., 2015). With the prevalence of TBIs in organized collegiate athletics, TBI protocols have been enabled to ensure comprehensive assessment of any sport related TBI by using ImPACT for baseline and post injury TBI evaluation, thereby aiding the collection and assessment of injuries to the cognitive domains (Broglio et al. 2017; Bruce & Echemendia, 2009). The evaluation of past data indicated that soccer players are more prone to TBIs with females being much more likely than males to suffer from TBIs (Conneely & Matzkin, 2015; Maher et al., 2014). Hence, concussion education may be increasing in contact sports, management support and awareness of recommendations to not play and seek medical attention is lacking in female athletics. Most importantly, female soccer players are more likely to continue play while injured and do not self-report symptoms as research shows that this group need increase education on concussion symptoms (O'Kane et al., 2014). Relatively, few studies have focused on the effect of TBIs on female collegiate athletes. The findings from this research suggest that concussion injuries in female collegiate soccer athletes are significantly associated with deficits in neurocognitive markers as measured by verbal working memory and reaction times.

Interpretation of the Findings

The study relied on the theoretical framework of the theory of mind (ToM), which is defined as the cognitive, affective, and social capacity to attribute one's own mental state, as well as having the inference of another person's mental state (Bellerose et al., 2017). This study focused on ToM's association with executive functioning, as the latter is significant in the process of regulating thoughts, actions, and updating working verbal memory (Austin et al., 2014; Honan et al., 2015).

Concussions are regarded as a mild form of TBI, based on the classification score of the severity of TBIs as derived from the Glasgow Coma Scale (GCS; Teasdale & Jennett,1974). Concussions affect various cognitive domains that include the executive function, learning, memory, attention, and processing speed (McInnes et al., 2017; Rabinowitz & Levin, 2014). However, they are also the most prevalent forms of TBIs, with about 15 percent of concussed individuals reporting persistent post-concussion syndrome, making it a dangerous and widespread form of TBI (Daneshvar et al., 2011; Marshall et al., 2015; McInnes et al., 2017). Moreover, concussions disrupt the nervous system responsible for controlling cognitive functions, resulting in a decline in cognitive function and other behavioral defects, reduced response under pressure, delayed reaction times, and reduced executive functioning (Danna-Dos-Santos et al., 2018; Dymowski et al., 2015; McInnes et al., 2017; Miotto et al., 2010; Woods et al., 2015). Bellerose et al. (2015) noted that children with a history of traumatic head injuries had difficulties in establishing tasks pertaining to emotion, desires, and false belief. Similarly, Rabinowitz and Levin (2014), found that TBIs had a significant impact on the long-term wellbeing of an individual. Additionally, Covassin et al. (2010) found that individuals affected by concussion took about three weeks to return to normal cognitive function – measured by verbal memory performance, thus corroborating the study by McClincy et al. (2006), which stated that concussed individuals take about one to two weeks to return to baseline cognitive performance. Accordingly, one can understand and study the effect of TBI on cognitive performance (Bellerose et al., 2017; Wang & Su, 2013).

Previous research examined the effects of TBI on cognitive performance based on ToM. This research examined the effect of TBI on two cognitive domains of neurocognitive capacity, verbal working memory and reaction time. Research shows as detrimental effects on reaction time and verbal working memory were found to be associated with a decline in student performance across academics, athletics, and a reduction in the overall quality of life (Ransom et al., 2015; Yengo-Kahn et al., 2016). Danna-Dos-Santos et al. (2018) reported that concussed individuals suffered in their ability to react to audio-visual stimulants in their environment. Similarly, Womack et al., (2017) reported that affected individuals had longer reaction times as compared to baseline values. From the obtained findings, research question one had a statistically significant outcome that rejected the null hypothesis that there are no significant differences in reaction times among NCAA collegiate female student-athlete soccer players after experiencing a head injury ($t(32) = 3.149$, $p = 0.004$). The current study contradicts this view by (Womack et al., 2017). This may be misleading as this study was of a small effect size and could represent small sample bias. Moreover, Wood and Wolgemuth (2019) reported concussions to be associated with chronic cognitive-linguistic deficits that have adverse effects on the verbal working memory. The result of research question 2, indicated no differences in verbal working memory deficits among NCAA collegiate female student-athlete soccer players after experiencing a head injury ($Z = -.185$, $p = 0.853$), accepting the null hypothesis.

Pellman et al. (2006) reported that age could be a mediating factor in recovery time and injury management among college athletes, with affected high school-aged athletes taking longer to return to baseline when compared to collegiate athletes. This study found no significant differences between baseline and post injury in reaction times when comparing age groups between NCAA collegiate female student-athlete soccer players after experiencing a head injury, accepting the null hypothesis with outliers ($t(31) = -.234$, $p = .816$) and without outliers ($t(16.896) = 0.087$, $p = .931$); it also found differences in baseline and post injury verbal working memory when comparing age groups between NCAA collegiate female student-athlete soccer players after experiencing a head injury were statistically significant in research question four ($U = 71.5$, $p = .04$) after a contradicting finding results with and without outliers did not agree. This implies that age could be a mediating factor when assessing the impact and recovery time from concussion injuries that affect reaction time and verbal working memory. I suspect that athletic programs are developing and focusing on consistent return to play protocols, concussion education, and biological factors of age groups. New program policies based on research findings such as how age group differences in verbal working memory and reaction time can contribute to the health and safety of collegiate female soccer athletes.

Limitations of the Study

The current study utilized only two markers to assess the impact of TBI on neurocognitive function – reaction time and verbal working memory. However, these two markers were identified as these are the most affected neurocognitive functions as reported by multiple studies (McInnes et al., 2017). Moreover, the study does not compare male and female athletes, thereby not adding to the existing research on whether female athletes are more susceptible to concussion injuries as compared to male athletes. Similarly, the study does not compare collegiate and high school athletes, thereby failing to add to the existing research where education level could be considered a mediating factor on susceptibility and recovery time associated with concussion injuries.

Another possible limitation associated with the study is the reliability and validity of the ImPACT tool. While some researchers have addressed the tool as unreliable, quite a few researchers have reported high reliability for the same (Lovell & Collins, 2003; Mayers & Redick, 2012). This study accounted for the concerns pertaining to reliability by utilizing the Cronbach's alpha reliability test to determine reliability.

Additionally, the study had a small sample size due to its focus on only collegiate female student-athletes who actively participated in college soccer. Additionally, the study accounted for only those students who were enrolled in NCAA colleges and who had taken ImPACT assessments, further restricting the sample size. Moreover, another factor that limited the sample size was the decision to utilize data from only those schools that were listed on the ImPACT website, while ignoring other schools that utilized HeadMinder to conduct neurocognitive assessments. This is because ImPACT has been found to be more representative of the two with athletic programs (Covassin et al., 2009). However, future research utilizing HeadMinder data, would add value to analyze its' neurocognitive assessments. Additionally, the study did not control for pre-existing variations in the neurocognitive performance of students. Hence, the study was generalizable to only female collegiate student-athletes who played soccer, had concussion history and relevant injury data listed on ImPACT.

Recommendations

The research indicated that concussions have a significant detrimental effect on reaction times and verbal working memory among female collegiate soccer athletes. Additionally, older female athletes display greater resistance to injury as compared to younger female athletes, thus implying that age could be an important mediating factor in concussion injuries. Further research is necessary to validate the same. Other relevant executive functioning factors or qualitative research may offer additional insight to female athletes and concussion management. It is recommended that female soccer players are required to wear protective headgear and further research must be conducted on the effectiveness of protective headgear to reduce the risk of concussion in soccer. Moreover, it is important to educate young female athletes with respect to concussion signs, symptoms, and protocols. This will ensure that more athletes can avail medical treatment before the deterioration or aggravation of existing injuries. Return to play policies are critical in the role of evaluating the severity of concussion symptoms and the decision of when to have an athlete return to active playing in their sport. Finally, improvements in training patterns and concussion education, could help improve injury recovery, thereby making them less susceptible to concussion related injuries.

Implications

The results implied that a concussion has a significant negative impact on the neurocognitive functions of female athletes, affecting reaction times as well as verbal working memory. Moreover, age induces greater resistance to injury from concussion. Thus, it is important to identify and enable protective factors that could reduce the risk of head injury among NCAA female collegiate soccer athletes and protect them better. As this study was of a small and medium effect size, the subfields of executive functioning (reaction time and verbal working memory) were just two cognitive domains that were analyzed. In a larger context, the problem of concussions in sports can be tackled by examining reliable quantitative and qualitative research designs by conducting small, medium, and large population samples. Clinical trials and theoretical significance are important in the resolution to implement concussion study results to athletic programs as the effects of concussions have impacted the micro and macro level of health and safety. Private and public organizations, research groups, government and medical institutions can assist in further research to explore concussion implications at all levels of an athletes' career.

Conclusions

Concussion injuries are the most prevalent form of TBIs, with studies indicating that female athletes are more prone to concussion related injuries as compared to male athletes. Given the prevalence of the injuries, their detrimental effect on academic, athleticism and overall quality of life, and the lack of research pertaining to the effect of concussion among female collegiate athletes, this study aimed to fill the gap in research with regards to the same. Accordingly, this study identified a statistically significant association between concussion injuries and deficits in neurocognitive functions among NCAA collegiate female student soccer athletes. Concussions had a negative effect on verbal working memory as well as reaction times. Surprisingly, while, age did not affect the changes in baseline and post injury reaction times, there was a significant difference in the changes in baseline and post injury verbal working memory scores among younger and older female athletes. Older female athletes displayed greater resistance to injury as compared to younger female athletes, thus implying that age could be an important mediating factor in concussion injuries. Concussion education for high school athlete parents is key to increase concussion knowledge about the health and safety of concussion symptoms. Further research is required to validate these concerns. Additionally, research must be carried out to identify protective factors and enable strategies that could reduce the risk of head injury among NCAA female collegiate soccer athletes and protect them better. Some proposed recommendations are to include education in informing female athletes with regards to identifying the signs and symptoms of concussions, mandating the usage of protective headgear in contact sports like soccer. Implementing administrative protocols and policies added from research results that will impact social change towards informative and healthy strategies for athletes to have a positive experience as a NCAA student athlete.

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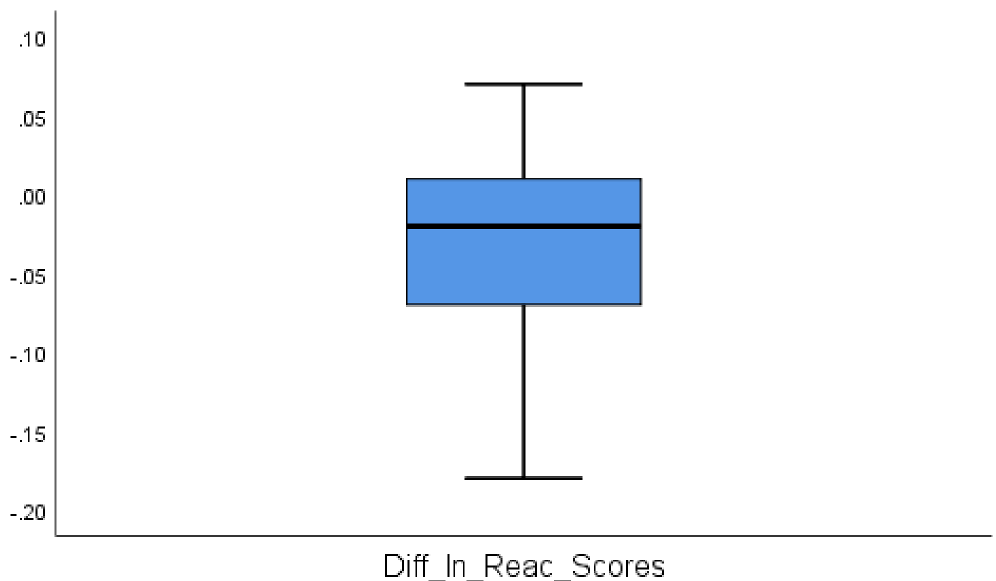
Appendix A: Checklist to Filter Data

1. Gender
   Female data only
2. Concussion Type
   1st. 2nd, 3rd, 4th
3. Number of Concussions
4. Concussion History
5. Educational Level
6. Primary Position
7. Age group
   (17-19) and (20-22)
8. Level of Participation

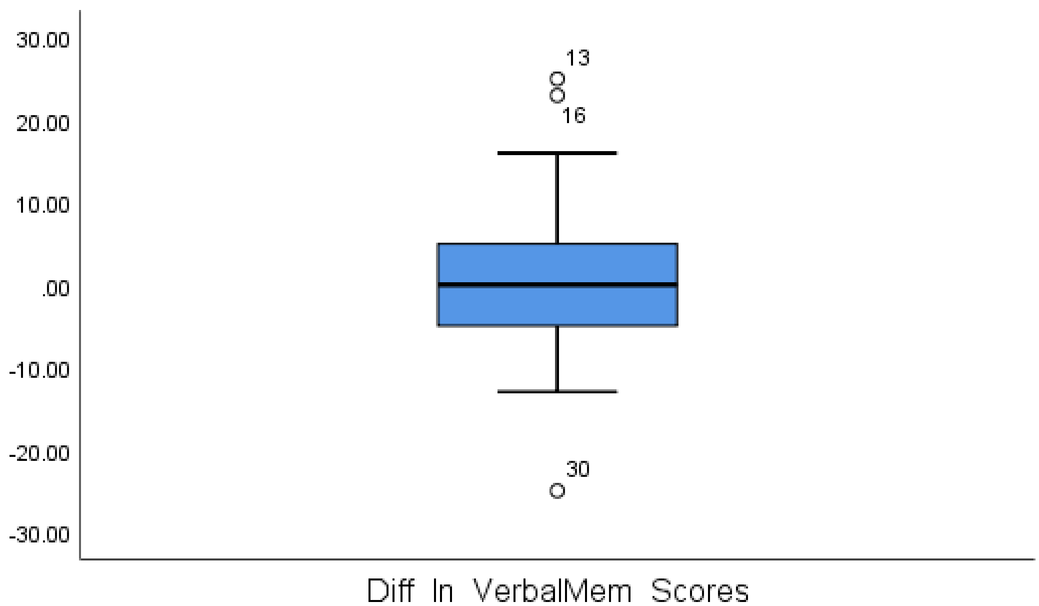
Appendix B: Boxplot 1

RQ_1: Based on executive functioning factors of the theory of mind, are there significant baseline and post injury differences in reaction time between NCAA collegiate female student-athlete soccer players after experiencing a head injury?



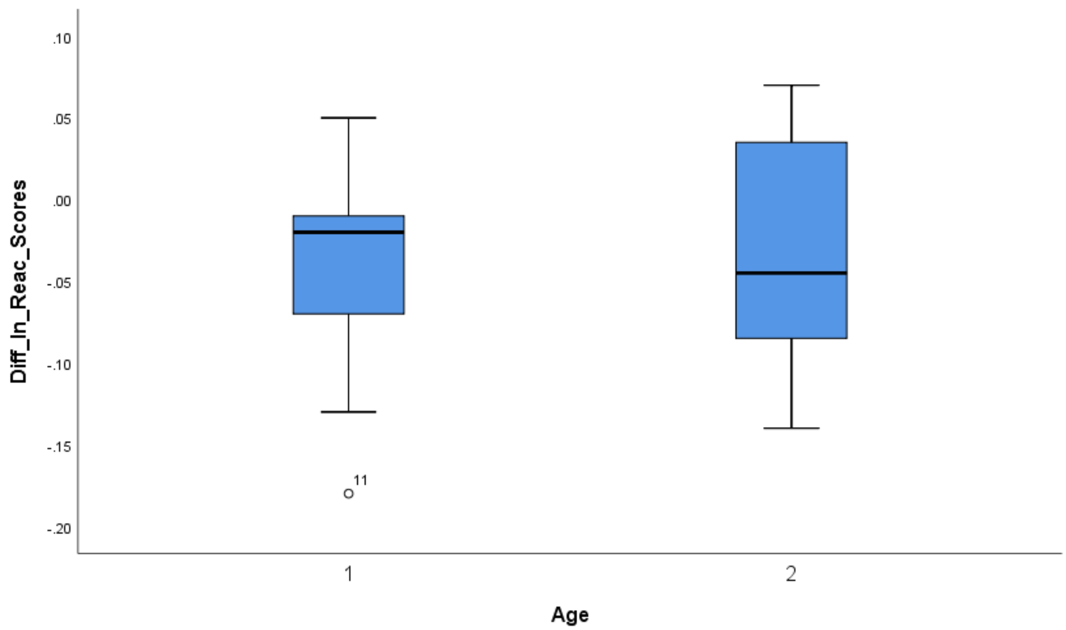
Appendix C: Boxplot 2

RQ_2: Based on the executive functioning of the theory of mind, are there significant baseline and post injury differences in verbal working memory deficits between NCAA collegiate female student-athlete soccer players after experiencing a head injury?



Appendix D: Boxplot 3

RQ$_3$: Based on executive functioning factors of the theory of mind, are there significant baseline and post injury differences in reaction time when comparing age groups between NCAA collegiate female student-athlete soccer players after experiencing a head injury?



Appendix E: Boxplot 4

RQ4: Based on executive functioning of the theory of mind, are there significant baseline and post injury differences in verbal working memory deficits when comparing age groups between NCAA collegiate female student-athlete soccer players after experiencing a head injury?