IMPACT BASELINE COMPOSITE SCORE DIFFERENCES AMONG STUDENT ATHLETES

A Dissertation
Submitted to the School of Education

Duquesne University

In partial fulfillment of the requirements for
the degree of Doctor of Philosophy

By
Kerry K. Schutte

August 2019
Copyright by

Kerry K. Schutte

2019
DUQUESNE UNIVERSITY
SCHOOL OF EDUCATION
Department of Counseling, Psychology, and Special Education

Dissertation

Submitted in partial fulfillment of the requirements for the degree
Doctor of Philosophy (Ph.D.)

School Psychology Doctoral Program

Presented by:

Kerry K. Schutte
M.S.Ed. Child Psychology, Duquesne University, 2014
B.S. Psychology, Edinboro University of Pennsylvania, 2013

June 21, 2019

IMPACT BASELINE COMPOSITE SCORE DIFFERENCES
AMONG STUDENT ATHLETES

Approved by:

_____________________________________________, Chair
Ara J. Schmitt, Ph.D.
Associate Professor
Department of Counseling, Psychology, and Special Education
Duquesne University

_____________________________________________, Member
Kara E. McGoey, Ph.D.
Professor
Department of Counseling, Psychology, and Special Education
Duquesne University

_____________________________________________, Member
Gibbs Y. Kanyongo, Ph.D.
Professor
Department of Educational Foundations and Leadership
Duquesne University

_____________________________________________, Member
Erica Beidler, Ph.D.
Assistant Professor
Department of Athletic Training
Duquesne University
ABSTRACT

IMPACT BASELINE COMPOSITE SCORE DIFFERENCES AMONG STUDENT ATHLETES

By
Kerry K. Schutte
August 2019

Dissertation supervised by Ara. J. Schmitt, Ph.D.

The ImPACT aims to measure neurocognitive functioning in student athletes. Many schools administer preseason ImPACT assessments to determine athletes’ baseline functioning. Follow-up ImPACT assessments are administered to athletes who sustain concussions to compare their pre- and post-injury functioning. Normative data may be used in place of individualized baseline scores if athletes were not administered baseline assessments. At the inception of this study, normative datasets consisted of scores from typically developing athletes. However, research suggests athletes of varying gender and exceptionality statuses perform differently on baseline ImPACT assessments. In particular, differences were found among male and female athletes as well as athletes with learning disabilities (LD) and attention-deficit/hyperactivity disorder (ADHD) when compared to control groups. Although some studies have suggested gifted and/or talented students may perform differently on ImPACT baseline
assessments, no present study has directly examined this concept. The present study investigated baseline score differences between males and females and among students with LD, ADHD, giftedness, and typical development on the five composites of the ImPACT (Verbal Memory, Visual Memory, Visual Motor Speed, Reaction Time, Impulse Control). Findings of the present study revealed significant main effects of exceptionality status. Contrary to initial hypotheses, no significant main effects of gender were found. Additionally, no significant interaction effects were discovered. Follow-up analyses revealed members of the Gifted group obtained significantly higher scores than members of the Control group on Verbal Memory and Visual Memory Composites. The importance of these findings, limitations of the study, and directions for future research are also discussed.
DEDICATION

This dissertation is dedicated to all my family and friends who constantly encouraged and supported me in all of my personal, academic, and professional endeavors throughout my life. I am so grateful to my parents, fiancé, siblings, friends, and cohort members for listening to me, working with me, helping me, and pushing me to pursue and complete my goals. Also thank you all for convincing me to take breaks as needed and engaging in leisure and self-care activities with me when necessary. I would not have been able to fulfill my accomplishments without all of your patience, guidance, understanding, and love!
ACKNOWLEDGEMENT

First, I would like to express gratitude to my committee chair, Dr. Ara J. Schmitt. I am so thankful for your endless guidance and support throughout my years at Duquesne. I am honored to have a mentor who is always easily accessible, genuinely interested in my endeavors, consistently offering honest insight and support, and able to share a great sense of humor when needed. I would also like to express sincere gratitude to my other committee members, Dr. Kara E. McGoey, Dr. Gibbs Y. Kanyongo, and Dr. Erica Beidler. Thank you all so much for your patience, insight, and assistance throughout the dissertation process. All of your expertise and feedback was crucial to the completion of this document. Thank you all for your time and interest.

Thank you also to Audrey Czwalga for greeting me daily with a smile and delightful conversation while also keeping me on track for completing program related responsibilities. I would also like to thank Dr. Glen Getz for providing an incredible practicum experience that allowed me to gain more autonomy and confidence in my assessment and report writing abilities in such a creative, supportive, and engaging environment. Thank you to Dr. Courtney Gotschall for endless kind words, constant positive support, regular dissertation check-ins, and invaluable therapeutic insight and expertise. I would not have been able to successfully complete my internship experience without your encouragement and investment. Lastly, thank you to Dr. Peter McLaughlin for providing me with my first research experiences in such a collaborative and caring laboratory environment. I would not have considered, or thought it possible, to complete a doctoral program without your constant guidance, support, and motivation.
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abstract</td>
<td>iv</td>
</tr>
<tr>
<td>Dedication</td>
<td>vi</td>
</tr>
<tr>
<td>Acknowledgement</td>
<td>vii</td>
</tr>
<tr>
<td>List of Tables</td>
<td>ix</td>
</tr>
<tr>
<td>List of Figures</td>
<td>x</td>
</tr>
</tbody>
</table>

## CHAPTER 1: INTRODUCTION

Concussions in Student Athlete Populations ......................................................... 1
Concussion Prevalence and Risk Factors ............................................................. 3
General Sports Training Guidelines and Pediatric Practice Parameters ............. 4
Theoretical Basis of Study ...................................................................................... 7
Overview of ImPACT Literature ........................................................................... 11
Problem Statement ................................................................................................. 12
Research Questions and Hypotheses ..................................................................... 13

## CHAPTER 2: LITERATURE REVIEW

Foundational Concepts............................................................................................ 15
Concussions ................................................................................................................ 16
Definition of Concussion .......................................................................................... 16
Concussion Prevalence ............................................................................................. 18
Symptoms and Neuropsychological Consequences .......................................... 19
Concussions in School Sports ................................................................................. 22
Causes and Prevalence ............................................................................................ 22
Conclusions Regarding Exceptionality Status .................................................. 79

Conclusions Regarding Gender ........................................................................ 84

Study Limitations ............................................................................................... 85

Recommendations for Future Research ............................................................ 88

Implications ......................................................................................................... 89

Summary .............................................................................................................. 90

REFERENCES ...................................................................................................... 92
LIST OF TABLES

Table 1. Classification Ranges for ImPACT Composite Score Normative Data for Males Ages 13 to 15 .......................................................... 54
Table 2. Classification Ranges for ImPACT Composite Score Normative Data for Females Ages 13 to 18.......................................................... 55
Table 3. Frequency Distribution: Entire Sample Demographics ...................................... 69
Table 4. Frequency Distribution: Sample Demographics by Groups ....................... 70
Table 5. Box’s Test of Equality of Covariance Matrix................................................. 72
Table 6. Levene’s Test of Equality of Error Variances among the ImPACT Baseline Composite Scores Based on Median........................................ 73
Table 7. Pearson Correlation among the ImPACT Baseline Composite Scores ............ 73
Table 8. Shapiro-Wilk Tests of Normality .............................................................. 74
Table 9. Means and Standard Deviations of Gender and Exceptionality Status on the Dependent Variables......................................................... 75
Table 10. Multivariate Test Results, Wilks Lambda Distribution................................. 76
Table 11. Tests of Between-Subjects Results for Exceptionality Status ......................... 76
CHAPTER I

INTRODUCTION

Concussions in Student Athlete Populations

Organized sports participation is considered to be a popular recreational activity in the United States. Roughly 69 percent of children between the ages six and 12 have participated in an organized team or individual sport in the year 2017 (Aspen Institute, 2019) and almost eight million high school students attending public school districts participated on at least one type of sports team during the 2017-2018 academic school year (National Federation of State High School Associations, 2019). The number of US children and adolescents involved in organized sports continues to increase every year. More specifically, an additional 18,000 high school students participated in school-based sports teams during the 2017-2018 school year as opposed to the 2016-2017 academic school year (National Federation of State High School Associations, 2019). More students engage in organized sports with each new academic school year. This is a trend that has continued upwards for the past 29 academic school years (National Federation of State High School Associations, 2019).

Although sports participation is associated with various physical, psychological, and social benefits (Hedstrom, Ryan, & Gould, 2004), risk of sports-related injury is well documented in literature as well (Burt & Overpeck, 2001). Specifically, sports-related injuries are more likely to involve brain, skull, and extremity trauma than non-sports related injuries. In fact, approximately 1.6 to 3.8 million sports-related concussions occur every year in the United States (Harmon et al, 2013; Zuckerman et al., 2015). Concussions can cause a range of functional impairments and may result in physical, behavioral, and/or cognitive changes in everyday functioning (McCrorry et al., 2013). Symptoms of concussion typically include
headache, neck pain, nausea, dizziness, tiredness, ringing ears, and/or dazed sensations (World Health Organization, 2013). A concussed athlete may also experience an inability to maintain coherent thoughts, a disturbance in awareness and distractibility, and an inability to complete sequential goal-directed movements (American Association of Neurological Surgeons, 2015). This suggests that sports-related concussion can result in many cognitive impairments that may impede a student athlete’s daily living.

Student athletes may demonstrate concussion symptoms in the classroom as well, and these can negatively impact student learning. School-aged athletes experiencing concussion symptoms in the school environment may ultimately have difficulty learning new tasks, remembering previously learned material, and attending school (Halstead et al., 2013). This suggests that student athletes with concussion require careful diagnosis, treatment, and symptom management. Neuropsychological assessment can help sports physicians and school officials estimate recovery time and make data based return-to-learn and return-to-play decisions for student athletes with concussion (McCrory et al., 2013). These tests allow for comprehensive assessment of different cognitive domains and coexisting mental health conditions (Harmon et al., 2013). Although concussions are commonplace in child and adolescent sports, limited research exists on childhood sports-related concussions (Halstead & Walter, 2010). Currently, there is insufficient research in the area of pediatric concussion assessment, treatment, and management, especially for children under the age of ten (Zemek, Farion, Sampson, & McGahem, 2013). This indicates that pediatric sports-related concussion must be further researched to ensure proper assessment and treatment of young concussed athletes.
Concussion Prevalence and Risk Factors

Concussion prevalence rates in adolescent student athletes have nearly doubled over the past decade (Marar, McIlvain, Fields, & Comstock, 2012). Although concussion rates have increased in pediatric athlete populations over the past few years, the precise prevalence rates of concussion in grade school student athletes are unknown (Halstead & Walter, 2010). Limited research on this population in this area prevents accurate estimates from being calculated. A small literature base is concerning when considering that concussion is one of the most common types of head injury among students involved in organized school sports (Sarmiento, Mitchko, Klein, & Wong, 2010). The level of risk for concussion in child and adolescent student athletes depends on a number of different factors. One factor that influences concussion risk is the type of activities the athlete engages in while playing a specific sport (Powell, 2001). Young athletes who engage in contact sports are at high risk for concussion (Carmen et al., 2015). Intuitively, child and adolescent athletes who engage in these types of sports are most susceptible to brain-related injuries.

Contact sports require athletes to purposely or routinely make physical contact with one another or with inanimate objects as part of game play (Rice, 2008) and places student athletes at the highest risk for bodily injury, including concussion (Powell, 2001). Football, hockey, basketball, lacrosse, soccer, and wrestling are commonly considered contact sports (Committee on Sports Medicine & Fitness, 1994). Football, basketball, and soccer are three of the top 10 most popular sports played by male high school student athletes while basketball, soccer, and lacrosse are three of the top 10 most popular sports played by female high school student athletes in the United States (National Federation of State High School Associations, 2014). Additionally, more than one million high school students participate on school-affiliated football
teams and over 35,000 play on school-affiliated ice hockey teams in the US (National Collegiate Athletic Association, 2015). These data suggest that a significant number of young student athletes are at high risk for concussion and the need for more research in the area of sports-related concussion with grade school aged students.

Another factor that influences concussion risk is age. Child and adolescent athletes are still developing and are typically physically weaker than adult athletes. As a result, child and adolescent athletes can acquire concussions at lower impact forces and tend to require longer recovery periods than adult athletes (Daneshvar et al., 2011). Additionally, long-term neuropsychological concussion symptoms often have greater impact on younger athletes (Daneshvar et al., 2011) and can more adversely affect student athletes’ schoolwork and classroom performance (Karlin, 2011). Long-term neuropsychological consequences are rare however. Concussion symptoms tend to be relatively immediate and short-term (Whyte, 1998) and may include loss of consciousness, amnesia, blurred vision, irritability, slowed reaction times, and insomnia (McCrory et al., 2013). Common symptoms of concussion that students may display in the classroom are slowed processing speed, trouble staying awake, anxiety problems, decreased concentration, attention deficits, and memory difficulties (Sady, Vaughan, & Gioia, 2011). This suggests that understanding the main causes and symptoms of concussions in school sports is important, especially when a vast number of students participate in these sports and suffer from concussion.

**General Sports Training Guidelines and Pediatric Practice Parameters**

Concussion management guidelines were created to help assess and manage concussions in student athlete populations. Research in this specific area has swiftly developed over the past few years (Gibson, Herring, Kutcher, & Broglio, 2015). Concussion prevention is considered one
of the most important measures for avoiding concussions in school sports (Frey, Savage, & O’Shanick, 2009). However, student athletes are still at risk for concussion even with appropriate prevention measures in place. As a result, current sports-related concussion guidelines suggest preventive measures as well as assessment, treatment, and management techniques. These guidelines suggest that athletes must receive post-concussion evaluations immediately following a suspected head injury (McCrory et al., 2013). According to recent guidelines, athletes injured during game play are also recommended to receive follow-up medical and neuropsychological evaluations from licensed health care providers (Kirschen, Tsou, Nelson, Russell, & Larriviere, 2014). These follow-up evaluations allow for athletes’ symptoms to be assessed, treated, and monitored (Kirkwood, Yeates, & Wilson, 2006). All states in the U.S. and the District of Columbia have passed laws regarding the prevention, assessment, and management of sports-related concussions in student athletes (Gibson et al., 2015). These laws aim to reinforce guidelines that educate coaches, athletes, and parents of athletes about the dangers of concussion, remove any athlete from game play if he or she is suspected of having sustained a concussion, and require clearance from an authorized medical professional before an athlete can return to game play (Esquivel, Haque, Keating, Marsh, & Lemos, 2013; Gibson et al., 2015).

Neuropsychological assessment is an important part of comprehensive concussion assessment and management planning. When administered in conjunction with other assessments, results obtained from neuropsychological tests help enable effective concussion diagnosis and treatment planning (McCrory et al., 2013). Current concussion guidelines and laws promote the use of baseline neuropsychological assessment data to aid in the identification of subtle cognitive deficits and individualized treatment decision making (Karlin, 2011). Preseason baseline data allows for an athlete’s neuropsychological functioning to be compared pre- and
post-injury. This baseline data provides health care providers with an athlete’s normal, preinjury cognitive functioning levels (Guskiewicz et al., 2004). Individual post-concussive test scores can be compared with benchmark scores to better assess and treat symptoms and cognitive impairments associated with concussion.

Sometimes normative data is used for as athlete’s baseline data if he or she did not personally receive a preseason baseline assessment before acquiring a concussion (Doolan, Day, Maerlender, Goforth, & Brolinson, 2011). Normative data are based on typical baseline test scores obtained from the general population of student athletes, however, and may inaccurately represent baseline scores for athletes with preexisting learning disabilities (LD), attention deficit hyperactivity disorder (ADHD), and high cognitive functioning levels (Grindel, Lovell, & Collins, 2001). Currently there are no separate normative baseline data for athletes with these special considerations, which suggests that individualized baseline data for athletes with LD, ADHD, and high levels of academic achievement are a better indicator of pre-injury cognitive functioning than current normative baseline data (Echemendia et al., 2013). Presently there are gaps in the literature for athletes with these special considerations who are not administered baseline neuropsychological assessments. Student athletes with these considerations must either receive preseason, baseline testing or have normative data specific to their populations to compare to their post-concussion test results. This ultimately will aid in appropriate concussion treatment and management of students with LD, ADHD, and gifted status.

Neuropsychological assessment allows for comprehensive assessment of different cognitive domains (Harmon et al., 2013) and helps sports physicians make decisions about concussion management, recovery time, return to play, and return to learn (McCrory et al., 2013). Computerized neuropsychological assessments have recently been used in the field as
they allow for large numbers of athletes to be tested at the same time, efficient data scoring and storage, better assessment of reaction time and processing speed, randomization of test stimuli, and quick interpretation of results (Lovell, Collins, & Bradley, 2004). The Immediate Post-Concussion Assessment and Cognitive Testing (ImPACT) assessment is one of the most widely used computerized tests that measures neurocognitive functioning and concussion symptoms (Covassin, Elbin, Stiller-Ostrowski, & Kontos, 2009). This particular test measures attention span, sustained and selective attention, reaction time, verbal and visual memory, and processing speed (Borich et al., 2013). Research suggests that ImPACT effectively detects cognitive changes caused by concussion and is an effective tool for gauging neurocognitive deficits in neuropsychological evaluations (Schatz, Pardini, Lovell, Collins, & Podell, 2006). Although studies have found ImPACT to be a useful tool, computerized neuropsychological concussion assessment is a relatively new area of research and tests like the ImPACT must continue to be researched.

**Theoretical Basis of Study**

Cattell-Horn-Carroll (CHC) theory suggests that overall cognitive ability is comprised of a single overall intelligence construct as well as a variety of fluid and crystallized intelligence processes. A total of 16 broad abilities, and over 80 narrow abilities, exist in the current CHC model (Alfonso, Flanagan, & Radwan, 2005). The broad abilities in the present CHC model consist of general, acquired knowledge, and sensory and motor-linked ability domains (Schneider & McGrew, 2012). Fluid reasoning, short-term memory, long-term storage and retrieval, processing speed, reaction and decision speed, psychomotor speed, visual processing, and auditory processing are a few of the broad abilities categories included in the present model. This type of hierarchical cognitive abilities model is often utilized by intelligence test creators.
This suggests that CHC theory plays an important role in standardized cognitive test battery development and interpretation. Specifically, this theory aids in the classification of narrow cognitive abilities as assessed by subtests of intelligence test batteries (McGrew, 2009). Overall, CHC theory enables cognitive abilities to be examined as inter-related constructs that comprise overall cognitive functioning in modern assessment measures.

Additionally, Luria’s Working Brain model assumes that human mental processes are intricate systems that are occur throughout interconnected brain structures rather than localized in specific areas of the brain (Luria, 1973). This model proposes that each brain structure plays a specific role in the overall functioning of the brain. Luria suggested the brain is composed of three principle function units that are each accountable for different brain activities (Hale & Fiorello, 2004) such as arousal, attention, receiving information, encoding information, sorting information, executive planning, and organization (Languis & Miller, 1992). These principle functions are interdependent on one another to properly function, even though they primarily perform different cognitive tasks (Luria, 1973). Similar to CHC theory, Luria’s Working Brain model also provides a theoretical basis for some current standardized psychoeducational test batteries (Languis & Miller, 1992). This suggests that current intelligence and cognitive test batteries have been developed to assess some of the cognitive functions discussed in both theories. Both CHC theory and Luria’s Working Brain model allow for broad and narrow cognitive abilities to be understood as inter-related constructs that impact overall cognitive functioning in current assessment batteries.

Some of the cognitive abilities discussed in both CHC theory and Luria’s Working Brain are typically impacted by sports-related concussion injuries as well. Fluid abilities such as memory, attention, working memory, processing speed, and executive functioning are most
commonly affected by concussion (Barr & McCrea, 2001; Belanger & Vanderploeg, 2005; Bruce & Echemendia, 2003). This indicates that these theoretical concepts provide an empirical base in which the ImPACT can be compared to in order to justify its use as an acceptable neuropsychological assessment for student athletes at-risk for concussion. Moreover, results obtained from the ImPACT are used to generate Verbal Memory, Visual Memory, Visual Motor Speed, Reaction Time, and Impulse Control composite scores (ImPACT Applications, Inc., n.d.). The ImPACT also directly measures attention span, verbal and visual memory, working memory, response variability, reaction time, and non-verbal problem solving which are consistent with the some of the broad and narrow abilities in the CHC model and cognitive abilities in the principle function units in Luria’s Working Brain model. This suggests that the ImPACT is an appropriate, empirically supported neuropsychological assessment tool to examine student athlete performance on memory, motor speed, reaction time, and impulse control tasks in the present study.

Furthermore, Barkley’s Extended Phenotypes Theory suggests ADHD is a disorder of executive function and self-regulation and considers many symptoms of ADHD to be executive functions (Barkley, 2015). Barkley (2015) indicates executive functions should be considered as a multilevel hierarchy that consists of distinct developmental levels that serve as a foundation for development and growth of subsequent levels. According to this theory, these levels build upon one another to ultimately allow people to use culture and other people to consider, plan for, and complete complex actions to accomplish future goals. Barkley argues that a deficit in any one or more of any of these levels can result in deficits within the development of the other subsequent levels and lead to significant educational, social, occupational, and other forms of major life functions that rely on adequate executive functioning skills. People diagnosed with ADHD are
likely to exhibit deficits in executive functioning and self-regulation that impact their overall daily functioning. Taken altogether, Barkley’s Extended Phenotypes Theory provides theoretical rationale for why student athletes diagnosed with ADHD could obtain significantly poorer scores on the composite scores of the ImPACT assessment than their peers.

According to Meltzer and Krishnan (2007), the following six core executive processes are essential to obtaining adequate performance on complex academic tasks: planning and goal setting, organizing, prioritizing, memorizing, shifting flexibly, self-monitoring, and self-checking. Meltzer and Krishnan suggest students with learning disabilities display deficits within these six core functions which may lead to difficulty adequately initiating work, organizing, prioritizing, selecting appropriate goals, shifting strategies, and self-monitoring on academic tasks. When utilizing this theory, the academic performance and test-taking abilities of students with learning disabilities are likely to be negatively impacted by deficits in the aforementioned six executive functions. As a result, students with learning disabilities would be expected to obtain significantly poorer scores on the baseline ImPACT composite scores than typically developing or gifted peers.

Lastly, the Tripartite Model of Giftedness indicates three separate, but complementary ways to identify and assess for gifted and talented students which includes high intelligence, outstanding accomplishments, and the potential to excel (Pfieffer, 2015). The first category, high intelligence, refers to students who have above average intellectual abilities as commonly assessed through standardized IQ tests. The second category, outstanding accomplishments, are academically gifted learners and tend to perform extraordinarily well on academic assignments and in classroom activities. The third category, potential to excel, refers to students who are quick learners, hardworking, or highly curious who have high potential that is yet to be realized.
Pfieffer suggests gifted students’ academic needs are regularly unmet in the general education classroom, and they often need specialized academic programming or services to best meet their unique needs. This suggests that students identified as gifted may perform differently on the baseline ImPACT composites and require separate normative baseline data in the absence of individual baseline data.

**Overview of ImPACT Literature**

Recent research indicates that athletes with a learning disability (LD) or attention-deficit/hyperactivity disorder (ADHD) obtain significantly different scores on neuropsychological assessments and report larger numbers of concussion symptoms than athletes without these disabilities (Elbin, Kontos, Kegel, Johnson, Burkhart, & Schatz, 2013). More specifically, research suggests that students with LD or ADHD earn statistically lower (i.e. poorer) scores on the ImPACT Verbal Memory, Visual Memory, and Visual Motor Speed composites and statistically higher (i.e. poorer) scores on the ImPACT Reaction Time composite (Elbin et al., 2013). Although research on baseline ImPACT composite performance of students with exceptionally high levels of cognitive ability and academic achievement is nonexistent, some studies have identified a need for separate normative baseline concussion data for gifted student athletes (Marcotte & Grant, 2009). Other studies have urged future research to analyze associations between neuropsychological test score performance and intelligence (Brown, Guskiewicz, & Bleiberg, 2007). Overall, student athletes with LD, ADHD, or giftedness may be erroneously represented by normative baseline scores (Echemendia et al., 2013) because they are often excluded from studies researching baseline concussion normative samples (Iverson, Collins, Roberge, Lovell, 2008) This highlights the need for individual baseline testing or for the creation of normative baseline data specific to these populations. Regardless, more research in
this area is necessary to better assess, treat, and manage concussed student athletes with these exceptionality statuses.

Current research also suggests significant differences between male and female student athletes’ reporting of concussion-related symptoms and performance on baseline neuropsychological measures. Even though males are more likely to sustain brain injuries of any type, females are more likely to report obtaining a concussion. Multiple studies have found that female athletes reported significantly higher rates of concussion than male athletes (Gessel, Fields, Collins, Dick, & Comstock, 2007; Halstead & Walter, 2010; Harmon et al., 2013). Additionally, female athletes typically earn significantly higher scores on baseline verbal memory tasks and lower scores on visual memory tasks than male athletes (Covassin et al., 2006). Females also tend to demonstrate greater decline from baseline to post-concussion testing (Broshek et al., 2005; Colvin et al., 2009). Furthermore, concussion prevalence rates continue to increase in pediatric student athlete populations, regardless of differences between gender, which indicates this is an important area of future research studies.

**Problem Statement**

It is evident that student athletes with ADHD or LD earn significantly different scores than typically developing peers on the five baseline ImPACT composites (Elbin et al., 2013). It is also apparent that male and female student athletes perform significantly different on baseline concussion assessment measures (Covassin et al., 2006). Although some studies have identified a need for separate normative baseline concussion data for gifted student athletes (Marcotte & Grant, 2009) and urged future research to analyze associations between neuropsychological test score performance and intelligence (Brown, Guskiewicz, & Bleiberg, 2007), no known studies at the time of the proposal of the present study have directly investigated these topics. This
highlights the need for the present study. The current study will examine whether there are any score differences among male and female student athletes with various exceptionality statuses of ADHD, LD, or giftedness on a commonly utilized baseline neuropsychological assessment. The following questions will be investigated.

**Research Questions and Hypotheses**

The first research question in the present study investigated whether there were differences in baseline ImPACT composite scores earned among student athletes with different exceptionality statuses. Specifically, this research question investigated whether student athletes with ADHD/LD, giftedness, or typical development earned significantly different scores on the five baseline ImPACT composites of Verbal Memory, Visual Memory, Visual Motor Speed, Reaction Time, and Impulse Control. It was hypothesized that student athletes diagnosed with ADHD or LD would obtain significantly lower baseline Verbal Memory, Visual Memory, and Visual Motor Speed and significantly higher Reaction Time baseline ImPACT composite scores than student athletes identified as typically developing and gifted. Another hypothesis was that student athletes identified as gifted would obtain significantly higher baseline Verbal Memory, Visual Memory, and Visual Motor Speed and significantly lower Reaction Time and Impulse Control ImPACT composite scores than student athletes diagnosed with ADHD or LD and identified as typically developing.

The second research question in the current study investigated whether there were differences in baseline ImPACT composite scores earned among student athletes of different genders. Specifically, this research question investigated whether male and female student athletes earned significantly different scores on the five baseline ImPACT composites of Verbal Memory, Visual Memory, Visual Motor Speed, Reaction Time, and Impulse Control. It was
hypothesized that female student athletes would obtain significantly higher baseline Verbal Memory and Visual Motor Speed, as well as lower Reaction Time, composite scores than male student athletes. Another hypothesis suggested male student athletes would obtain significantly higher baseline Visual Memory composite scores than female student athletes.
CHAPTER II

LITERATURE REVIEW

Foundational Concepts

This chapter contains a review of the differences in baseline computerized neuropsychological test scores among student athletes with learning disabilities, attention deficit hyperactivity disorder, and giftedness. In the beginning of this literature review, the term concussion is defined and current prevalence rates are discussed. Symptoms and short-term and long-term neurological consequences of concussions are described as well. The next section of this chapter is comprised of a review of the most common causes and prevalence rates of concussions in school sports. General sports training guidelines and pediatric practice parameters, and how they are implemented in the school setting, are also discussed. Specific state legal codes and school district policies regarding concussion prevention, treatment, and management of concussed student athletes are examined in this section as well.

The next section of this literature review describes the purpose of neuropsychological assessment and the importance of this type of assessment as a part of concussion evaluation. A review of common neuropsychological concussion tools, followed by a detailed discussion of Immediate Post-Concussion Assessment and Cognitive Testing (ImPACT) assessment, is also included in this section. The next part of this literature review examines two theoretical perspectives associated with brain injuries and neuropsychological assessment. Finally, a review of literature specific to differences of ImPACT test scores among student athletes with learning disabilities, attention deficit hyperactivity disorder, and giftedness are included. This chapter concludes with the identification of this research area as relatively new and understudied, which stresses the need for the present study.
Concussions

Definition of concussion. Intracranial injuries are brain injuries caused by accidents, surgeries, or other traumas (World Health Organization, 2013). External bumps or blows to the head can cause intracranial injuries. These types of brain traumas include traumatic brain injury (TBI) and concussion. Traumatic brain injury is defined as an impact to the head or displacement of the brain within the skull that results in loss of consciousness (LOC), post-traumatic amnesia, disorientation and confusion, or neurological signs of injury (American Psychiatric Association, 2013). The severity of a TBI is determined at the time of injury and is classified as either mild, moderate, or severe. These classifications are contingent upon the duration of LOC, post-traumatic amnesia, and disorientation and confusion. Injury characteristics with longer durations are indicative of more serious TBI diagnoses.

Similarly, concussion is defined as a type of trauma that involves short-term loss of typical brain functioning as a result of a head injury (World Health Organization, 2013). This type of brain injury can be classified as mild, intermediate, or severe. Loss of consciousness may or may not, occur as a result of concussion. If a concussion results in LOC, the typical duration of unconsciousness is a few seconds. Loss of consciousness can endure for a number of hours in rare circumstances. Concussion is commonly associated with sports-related injuries and is most often a diagnostic term used in the sports medicine community (Bodin, Yeates, & Klamar, 2012). Although TBI and concussion share similar characteristics, TBI typically refers to more complicated and longer lasting brain injuries, while concussion generally refers to less complicated, short-term, and sports-related brain injuries.

Even with differentiated diagnostic criteria, mild TBI (MTBI) and concussion are often inconsistently defined in the current literature. The word concussion is frequently used as a
synonym for the term MTBI within existing literature (Bodin et al., 2012). Medical and other health professionals may refer to a concussion as an MTBI because a concussion is typically a less severe and non-life-threatening brain injury (Center for Disease Control and Prevention, 2015a). The synonymous use of these terms prompted several professional organizations to revise each injury’s definition to better distinguish between similar diagnostic characteristics. In the updated edition of The International Statistical Classification of Diseases and Related Health Problems (ICD-10), concussion and TBI are listed as two separate types of intracranial injury (World Health Organization, 2013). Specific qualification categories are incorporated into concussion diagnostic criteria in the new ICD-10 as well. These categories include concussion with or without loss of consciousness, duration of loss of consciousness, and concussion with or without return to preceding conscious level. The specific qualifications included in the ICD-10 help to better distinguish concussion and TBI diagnostic criteria.

Furthermore, the Concussion in Sport Group (CISG) reviewed the operational definitions of concussion and MTBI during a panel discussion held at the Fourth International Conference on Concussion in Sport in 2012 (McCrory et al., 2013). The CISG recognized concussion as a distinct subtype of TBI. According to the panel, concussion symptoms generally have swift onset, short-term impacts on neurological functioning, and natural sequential resolution. Concussions also typically involve functional impairments in the brain rather than structural damage. In comparison, symptoms of mild, moderate, and severe TBIs are commonly delayed, long-term, and unrelenting. Traumatic brain injuries may also result in structural brain impairment that can be viewed with brain imaging technologies. Although a TBI can be classified as mild, this classification only refers to the initial physical trauma induced by the injury (Brain Injury Association of America, 2015). Symptoms of MTBI are considered to be
more severe than symptoms of concussion. Although the terms MTBI and concussion are interchangeably used throughout the literature, they are two distinct types of brain injury. The present study will use the term concussion to refer to any sports-related brain injury with quick onset, short-term functional impairments, and spontaneous sequential rehabilitation.

**Concussion prevalence.** According to the Centers for Disease Control and Prevention (CDC), approximately 1.4 million deaths, hospitalizations, and emergency department visits in the United States are caused by TBI every year (Centers for Disease Control and Prevention, 2015b). Concussions are estimated to account for 75 to 90% of these cases. The total number of emergency department visits related to concussive symptoms have increased almost 30% over the past few years (Zonfrillo, Kim, & Arbogast, 2015). These current prevalence rates of concussion in the US are considered to be underestimates, partly because people who receive treatment outside of hospitals and emergency departments are not included in the aforementioned approximations. Additionally, the number of people who acquire brain injuries and do not seek medical care is unknown (Langlois, Rutland-Brown, & Wald, 2006). This suggests that the actual number of people with concussions in the US is higher than currently estimated.

Concussions diagnosed in emergency departments are most commonly caused by falls (Langlois et al., 2004). Other major causes of concussion include motor vehicle collisions, accidental bumps or blows, assaults, and sports-related injuries. Specific age groups are considered to be at higher risk for concussion. This type of brain injury is most likely to occur in infancy, childhood, young adulthood, and geriatric populations (Langlois et al., 2004). Any person below the age of 24 or over the age of 75 is believed to be at high risk for concussion. Brain injuries tend to be more common among male populations as well. Males are one and a half times more likely to acquire a brain injury than females (Langlois et al., 2004). The numbers
of emergency department visits, hospitalizations, and deaths related to brain injury are almost
twice as high for males as they are for females. Although specific groups are more susceptible to
brain injuries, symptoms and neuropsychological consequences of concussions tend to remain
constant between age and sex.

**Symptoms and neuropsychological consequences.** Symptoms of concussion can consist of a variety of functional impairments. According to the ICD-10, symptoms may include headache, neck pain, nausea, dizziness, tiredness, ringing ears, and/or dazed sensations (World Health Organization, 2013). Another primary symptom of concussion is confusion. A person experiencing this symptom may experience an inability to maintain coherent thoughts, a disturbance in awareness and distractibility, and an inability to complete sequential goal-directed movements (American Association of Neurological Surgeons, 2015). Concussion may result in physical, behavioral, and/or cognitive changes in functioning as well. Loss of consciousness, amnesia, blurred vision, irritability, slowed reaction times, and insomnia may occur as a result of concussion (McCrory et al., 2013). Although many functional impairments caused by brain injuries are relatively immediate, they are also typically short-term. (Whyte, 1998). The majority of people who report symptoms of concussion to medical professionals recover completely within ten days post-injury (White, 2012). This suggests that most people who sustain a concussion normally experience fast, natural resolve of symptoms.

Although most people experience a quick recovery after acquiring a concussion, brain injury symptoms and recovery time are influenced by a variety of factors. These factors vary from person to person as well. More specifically, the location and severity of brain damage, comorbid medical conditions, preexisting mental health problems, and treatment procedures all influence the duration of neuropsychological consequences associated with brain injury.
(Rosenthal, 1998). Brain injury recovery time also typically depends on a person’s age. The brain tends to be structurally and developmentally different from childhood to adulthood and, therefore, symptoms and neuropsychological consequences of brain injuries may differ between children and adults (Daneshvar et al., 2011). Although approximately 80 to 90% of reported concussion symptoms are typically resolved within seven to ten days post-injury, children and adolescents may require longer recovery periods (McCrory et al., 2013). The duration of symptoms may persist for several days, or even weeks, after the initial injury (World Health Organization, 2013). This indicates that children and adolescents may experience, and suffer from, symptoms of concussion longer than adults because of biological and developmental immaturity.

In rare instances, concussion may result in long-term neuropsychological consequences. These long-term impairments may result in post-concussion syndrome (PCS) or chronic traumatic encephalopathy (CTE). The onset of PCS generally occurs within the first two weeks post-concussion and lasts for approximately three months (Mayo Clinic, 2014a). Although most individuals with PCS experience symptoms for a few months following brain injury, a limited number of people may experience symptoms for up to a year post-injury (Daneshvar et al., 2011, Mayo Clinic, 2014a). Post-concussion syndrome is typically defined as a medical condition that develops after the occurrence of a brain injury and causes somatic, psychological, and cognitive impairments (Hall, Hall, & Chapman, 2005). These long-term impairments may include headaches, dizziness, light sensitivity, blurred vision, depression, anxiety, irritability, apathy, forgetfulness, decreased concentration, memory impairments, and difficulties with learning, reasoning, and processing. Concussions acquired repeatedly over an extended period of time may result in a more severe condition known as CTE. Total number of brain injuries, type of brain
injuries, severity of all acquired injuries, other medical problems, and genetics are all factors that influence the development of CTE (Mayo Clinic, 2014b). Chronic traumatic encephalopathy causes gradual nerve cell damage in the brain which typically results in late onset physical, cognitive, emotional, and behavioral changes that can be long-lasting or permanent (World Health Organization, 2013). Common symptoms of CTE generally include memory problems, drastic behavioral and personality changes, speech difficulties, and gross motor disturbances (McKee et al., 2010). Furthermore, CTE is clinically similar to neurodegenerative diseases such as Alzheimer’s disease and Parkinson’s disease (Yi, Padalino, Chin, Montenegro, & Cantu, 2013). Although there are currently no effective treatments for CTE, establishing concussion management guidelines and enforcing return to play regulations may help prevent the onset of CTE in repeatedly concussed athletes (McKee et al., 2010, Yi et al., 2013). The enforcement of these guidelines is an important factor in deterring long-term consequences of sports-related concussion, especially within vulnerable populations like children and adolescents.

Recent studies suggest brain injuries that lead to long-term neuropsychological consequences typically have greater impact on children than adults (Daneshvar et al., 2011). Child and adolescent athletes involved in contact sports are at high risk for concussion and long lasting brain injury because their bodies are not fully developed yet (Carman et al., 2015). In other words, children and adolescents are generally weaker than adults. This causes young athletes to acquire brain injuries at lower impact forces and have longer recovery periods when compared to adults with similar injuries (Davis & Purcell, 2013). Additionally, long-term concussion symptoms may negatively affect a student athlete’s classroom learning and schoolwork (Karlin, 2011). These symptoms can cause students to exhibit slowed processing speed, trouble staying awake, anxiety problems, decreased concentration, attention deficits, and
memory difficulties in the classroom (Sady, Vaughan, & Gioia, 2011). Children experiencing these symptoms in the educational setting may ultimately have trouble learning new tasks, remembering previously learned material, and attending school (Halstead et al., 2013). A young developing brain may be more susceptible to poor post-injury recovery than a mature and fully developed brain as well (Pullela et al., 2006). More specifically, brain injuries acquired in childhood have been correlated with the development of learning deficits and anxiety expressed in adulthood. This suggests concussion management guidelines must be effectively implemented, especially in children and adolescent populations, in order to prevent long-term and debilitating neuropsychological consequences.

**Concussions in School Sports**

**Causes and prevalence.** Every sport is associated with a distinct level of risk for bodily injury. This level of risk is determined by the type of activities an athlete engages in while participating in a particular sport (Powell, 2001). Sports are most often categorized as contact, limited-contact, and noncontact to better assess levels of risk for bodily injury. In contact sports, athletes can purposely or routinely make physical contact with other athletes or inanimate objects as part of normal game play (Rice, 2008). Football, hockey, basketball, lacrosse, soccer, and wrestling are typically classified as contact sports (Committee on Sports Medicine & Fitness, 1994). These sports, and others that allow physical contact and collision between players, are considered to have the highest risk for bodily injury (Powell, 2001). Limited-contact sports generally involve infrequent and unintentional physical contact with other athletes or inanimate objects (Rice, 2008). Baseball, cheerleading, gymnastics, softball, and volleyball are commonly identified as limited-contact sports (Committee on Sports Medicine & Fitness, 1994). Although the risk of forceful physical contact and collision is lower in limited-contact sports, activities
associated with these sports can still be dangerous and cause serious injuries to athletes (Rice, 2008). Bowling, golf, dance, swimming, tennis, and track are typically categorized as noncontact sports (Committee on Sports Medicine & Fitness, 1994). Athletes can obtain serious injuries from noncontact sports even though physical contact is rare and risk of bodily harm is low (Rice, 2008). Assessing risk of sports-related injury is an important consideration for the physical well-being of athletes, especially in pediatric populations.

Concussion is one of the most common types of head injury student athletes acquire from participation in any sport (Sarmiento, Mitchko, Klein, & Wong, 2010). Most student athletes’ concussions are the result of falls and collisions during game play (Sarmiento et al., 2010). Football and hockey yield the highest risk for concussion because of forceful physical contact allowed in both sports (Koh, Cassidy, & Watkinson, 2003). Specific positions and styles of game play in these types of sports are correlated with varying levels of risk for concussion as well (Harmon et al., 2013). Some positions and activities within a sport require physical body-to-body contact and are considered to be high risk for concussion. For example, certain football positions require players to use their bodies to forcefully collide with opponents. Although student athletes who participate in contact sports are most likely to obtain concussions, student athletes who engage in non-contact sports are still at risk for brain injuries as well. Player collisions can occur in any type of sport and are a significant contributing risk factor for concussions in school sports (Powell & Barber-Foss, 1999). These types of collisions may include head-to-ball, head-to-body, and head-to-ground contact. Head-to-body collisions occur when two players crash into one another and are the cause of most concussions in the student athlete population (Marar, McIlvain, Fields, & Comstock, 2012). Recognizing and understanding the main causes of concussions in
school sports is important, especially when considering the number of students who participate in organized school sports and suffer from these injuries.

Approximately 69 percent of children between the ages of six and 12 living in the United States have played an organized team sport (Aspen Institute, 2019). Additionally, almost eight million high school students in public school districts have participated on at least one sports team (National Federation of State High School Associations, 2019). Overall, almost four million concussions are estimated to be the result of both competitive and recreational sports activities (Harmon et al., 2013). The pediatric population accounts for the majority of this estimate because of the considerable number of children and adolescents involved in organized sports (Halstead & Walter, 2010). Additionally, the prevalence rate of concussions in adolescent student athletes has increased more than twofold over the past decade. Concussions now account for approximately 13 percent of all reported high school sports-related injuries (Marar, McIlvain, Fields, & Comstock, 2012). Although many studies focus on concussions in high school student athletes, there is limited data gathered on concussions in grade school student athletes (Halstead & Walter, 2010). More research is needed to determine actual prevalence rates of sports-related concussion in the grade school population. Furthermore, gender plays an important role in prevalence rates of concussion in student athletes. Although males are more likely to acquire a brain injury of any type, females are more likely to report obtaining a concussion. Female athletes reported significantly higher rates of concussion than male athletes in sports played by both sexes (Gessel, Fields, Collins, Dick, & Comstock, 2007; Halstead & Walter, 2010; Harmon et al., 2013). Overall, concussion prevalence rates have increased in the pediatric student athlete population over the past few years, regardless of sex and age differences.
**General sports training guidelines and pediatric practice parameters.** Research on the assessment and management of concussion in the student athlete population has exponentially grown over the past ten years (Gibson, Herring, Kutcher, & Broglio, 2015). Prevention is one of the most important treatment recommendations for sports-related concussions (Frey, Savage, & O’Shanick, 2009). Although prevention of all brain-related injuries in school sports is improbable, many preventive measures can help reduce risk of concussion. Educating athletic personnel and students about the seriousness of concussions, promoting safer game rule changes, acknowledging individual players’ physical limitations, and wearing updated protective gear can all help to reduce risk of serious brain injury (Halstead & Walter, 2010). Although these preventive measures can lower the possibility of a sports-related injury, concussion can still occur. Student athletes still acquire brain injuries from participating in school sports, even with effective preventive measures in place (Powell, 2001). This suggests that, although risk of concussion can be successfully reduced, it can never be fully eliminated.

In attempt to reduce concussion risk and injury, the American Academy of Neurology (AAN) and the Brain Injury Association of America (BIA) published evidence-based guidelines for managing sports-related concussions in order to promote updated and unified prevention and treatment measures (Frey et al., 2009). These guidelines must be followed by team physicians, coaches, athletic trainers, and school personnel in order to provide appropriate assessment and management of concussions. The AAN and BIA established these guidelines hoping to further reduce athletes’ risk of concussion. According to the guidelines, team physicians, coaches, or trainers must instruct a player with a suspected concussion to cease game play immediately following an injury (Harmon et al., 2013). A player with suspected concussion should cease engagement in sports and any other type of physical activity until he or she is evaluated and
cleared by a medical health care professional (Rose, Weber, Collen, & Heyer, 2015). More specifically, a child or adolescent diagnosed with concussion during game play is not allowed to return to play the remainder of the game in which the injury was acquired.

Although a variety of sports training and concussion management guidelines have been published by different medical professionals and national associations, the majority of these guidelines include five main components for effective concussion management in children and adolescents. These components include preseason concussion prevention and assessment, immediate post-concussion evaluation, progress monitoring, return-to-play decision making, and non-sport considerations (Kirkwood, Yeates, & Wilson, 2006). Safety education for sports administrators, coaches, athletes, and parents of athletes is one of the most important aspects of injury prevention programs (Micheli, Glassman, & Klein, 2000). Athletes and their family members can help lower the risk of sports-related concussions by being knowledgeable of and supporting safe play techniques, training procedures, game rules, and use of protective equipment (Kirkwood et al., 2006). Medical health professionals can help prevent sports-related brain injuries by encouraging informed and shared decision-making among athletes, their parents, and medical teams (Kirschen, Tsou, Nelson, Russell, & Larriviere, 2014). Routine preseason assessments are also considered to be an important component of sports-related injury prevention and can encourage safe game play for athletes (American Academy of Pediatrics, American College of Sports Medicine, & American Academy of Family Physicians, 2010). These regularly administered assessments typically include a medical history review, physical examination, and evaluation of cognitive functioning.

Post-concussion evaluations must be conducted immediately following a suspected head injury (McCrorry et al., 2013). A physical examination of an athlete must be conducted first to
rule out medical emergencies such as spinal injuries, airway or breathing complications, and circulation problems (Harmon et al., 2013). Cognitive screenings should be administered to a player with a suspected concussion only after a physician examines the player and determines the absence of serious physical medical conditions (Kirkwood et al., 2006). Any athlete considered to have a medical emergency should be immediately transported to an emergency department for further evaluation (Rose et al., 2015). Additionally, athletes who obtain concussions during game play are recommended to receive follow-up medical and neuropsychological evaluations from licensed health care providers (Kirschen et al., 2014). Some symptoms of concussion may worsen overtime and follow-up evaluations allow for these symptoms to be assessed, treated, and monitored (Kirkwood et al., 2006). These symptoms may cause cognitive, physical, and behavioral impairments that place concussed athletes at high risk for repeated and more severe injury during game play (Rose et al., 2015). This highlights the importance of baseline and post-injury medical and neuropsychological evaluations of student athletes.

An athlete diagnosed with concussion can return to game play after no symptoms are observed during periods of rest and exercise and neuropsychological assessments yield typical results (Kirkwood et al., 2006). Furthermore, normal results must be obtained from neuroimaging devices if these technologies were used to determine brain injury in order for an athlete to return to play. Each athlete’s return-to-play must be gradual and stepwise (Rose et al., 2015). The CISG proposed five specific steps for athletes who wish to return-to-play (McCrorry et al., 2013). An athlete must be asymptomatic during each step to successfully advance to each subsequent step. According to the CISG, each step typically takes an athlete 24 hours to successfully complete. The first step includes light aerobic activity such as walking. After an athlete performs this type of physical activity without symptoms of concussion, he or she can
engage in sport-related training. This may involve activities like running or skating, depending on the athlete’s sport. The next step includes noncontact training drills. Once an athlete completes these drills without symptoms of concussion, he or she can then engage in full-contact practice training with clearance from a medical professional. The last step involves full return to game play. These guidelines allow student athletes appropriate recovery time and help prevent repeated injury (McCrory et al., 2013). Ultimately, these regulations should be actively enforced to help protect student athletes’ physical and cognitive wellbeing.

Non-sport considerations help children and adolescents adequately recover from concussion as well. These considerations involve implementation of individualized interventions and accommodations outside the athletic environment (Kirkwood et al., 2006). More specifically, these considerations target symptoms of concussion in the home and school settings. Student athletes recovering from concussion may demonstrate physical and cognitive impairments that negatively affect their schoolwork (McGrath, 2010). Physical and cognitive rest are two of the most common approaches to managing concussion in student athletes (May, Marshall, Burns, Popoli, & Polikandriotis, 2014). This promotes recovery by allowing students to take breaks from physical activities and cognitive tasks. Academic accommodations, including accommodations that allow cognitive rest, bolster quick recovery times for student athletes with concussions (Brown et al., 2014). Parents and teachers who are educated about concussions can promote a child’s recovery by individually modifying daily tasks and activities in order to meet each child’s specific medical needs (Broglio et al., 2014).

**State legal codes and district policies.** In 2009, Washington was the first state to pass a law with guidelines for reporting, documenting, and managing concussions in child and adolescent athletes (Bompadre et al., 2014). This law, known as the Lystedt Law, was named
after a student athlete who acquired severe neurological and physical disabilities from immediately returning to game play after sustaining a concussion (Adler & Herring, 2011). The Lystedt Law requires school districts to educate coaches, athletes, and parents of athletes about the risks and dangers of concussions, obtain informed consent from athletes and their parents about sports-related concussions, and remove athletes suspected of having concussion from play until they have been cleared by a licensed health care provider (Washington State Department of Health). The American College of Sports Medicine issued a statement at its 56th annual meeting urging all 50 U.S. states and the District of Columbia to pass concussion management laws for young athletes soon after the signing of the Lystedt Law in Washington (Adler & Herring, 2011). As of January 2014, all states in the U.S. and the District of Columbia have passed laws regarding the prevention, assessment, and management of sports-related concussions in student athletes (Gibson, Herring, Kutcher, & Broglio, 2015). These laws were formed to promote student athletes’ health as well as reduce sports-related injury lawsuits in schools (Wilson, 2010). Although specific legal guidelines regarding the prevention, assessment, and management of concussion in student athletes varies among states, most state laws include three main components (Esquivel, Haque, Keating, Marsh, & Lemos, 2013; Gibson et al., 2015). These critical aspects include preseason concussion education for coaches, athletes, and parents of athletes, prompt removal of any athlete from game play if he or she is suspected of sustaining a concussion, and clearance from an authorized medical professional before an athlete returns to game play.

The National Federation of State High School Associations (NFHS) and CDC encourage coaches, athletes, parents, school personnel, and medical professionals to adhere to concussion and return to play guidelines to reduce the risk of sports-related brain injuries (Wilson, 2010).
These guidelines may prove ineffective when they are not followed or enforced however (Amberg, 2012). More specifically, failure to comply with or invoke concussion guidelines in youth sports may lead to higher risk of injury and legal consequences. Athletes who are injured by others’ failure to comply with concussion management guidelines may be entitled to compensation under the U.S. negligence law (Osborne, 2001). School districts, school boards, and coaches are most commonly held legally responsible for negligence in sports-related concussions in the school environment (Wilson, 2010). As a result, the U.S. federal government has recently proposed legislature in attempt to hold schools accountable for enforcing sports-related concussion management guidelines.

The Concussion Treatment and Care Tools Act of 2009 (ConTACT) was proposed to amend the preexisting Public Health Service Act (Senate Bill 2840, 2009). This act would require the Secretary of Health and Human Services (HHS) to assemble a conference of medical, athletic, and educational professionals to develop distinct concussion management guidelines that outline prevention, identification, treatment, and management standards in child and adolescent student athletes. Additionally, ConTACT would enable the HHS to develop grants to ensure schools enforce these guidelines, as well as fund computerized preseason baseline and post-injury neuropsychological testing of all student athletes. Although this bill did not pass through Congress, it was reintroduced in January of 2015 and is awaiting action. Similarly, the Protecting Student Athletes from Concussions Act was introduced to Congress in April of 2015 (Senate Bill 988, 2015). This bill would require local educational agencies from each state to implement concussion management plans that educate students, parents, and school personnel about concussions, promote specific supports for students suffering from concussion, and identify best practices for concussion treatment and management. Furthermore, this act would
require schools to publicize concussion information, remove athletes suspected of concussion from sports-related activities until cleared by a licensed medical professional, and report all details of an athlete’s concussion to his or her parents. Although ConTACT and the Protecting Student Athletes from Concussions Act have not been passed by Congress and are expected to fail in Congress, future federal legislation may help ensure schools implement concussion guidelines and comply with state concussion laws to reduce risk of injury for student athletes (Wilson, 2010). The creation and enforcement of these laws could help to further reduce risk of concussion for student athletes.

Concussion Assessment

**Purposes.** Concussed athletes are typically administered post-concussion assessments within 24 hours of initial injury and continue to regularly receive these assessments until concussion impairments are alleviated (Broglio, Macciocchi, & Ferrara, 2006). Neuropsychological assessment is a valuable component of comprehensive concussion assessment and management planning. Results obtained from this type of assessment enable effective concussion diagnosis and treatment planning when administered in conjunction with other medical and clinical assessments (McCrory et al., 2013). Symptom rating scales are often administered as part of a thorough concussion assessment as well. Although standardized concussion symptom questionnaires produce reliable data about symptoms such as confusion and amnesia, these self-report measures are unable to assess other cognitive domains such as processing speed and memory (d’Hemecourt, 2011). More specifically, reports of post-concussion symptoms may not align with neuropsychological testing results because each assessment typically measures different cognitive processes (Lovell, 2002). Neuropsychological assessment ultimately allows subtle cognitive impairments to be objectively measured and can
aid in cognitive functioning assessment and rehabilitation (Harmon et al., 2013). This explains how assessment results may continue to yield atypical scores even after a person reports feeling asymptomatic (Doolan, Day, Maerlender, Goforth, & Brolinson, 2011). As a result, current concussion guidelines promote the use of baseline neuropsychological assessment data to aid in identifying subtle cognitive deficits and appropriate evidence based treatments (Karlin, 2011).

Baseline data allows for an athlete’s neuropsychological functioning to be compared pre- and post-injury. More specifically, baseline assessment data provides health care professionals with athletes’ typical pre-injury cognitive functioning (Guskiewicz et al., 2004). This allows for post-concussive neuropsychological test scores to be compared with an athlete’s individual preseason benchmark scores. Normative data can be used for an athlete’s baseline data if he or she did not receive a preseason baseline assessment before acquiring a concussion (Doolan et al., 2011). These normative data are based on typical baseline test scores obtained from the general population of student athletes. However, normative baseline data may inaccurately represent baseline scores for athletes with preexisting psychiatric problems, learning disabilities (LD), attention deficit hyperactivity disorder (ADHD), and high or low cognitive functioning levels (Grindel, Lovell, & Collins, 2001). More specifically, normative baseline data is secondary to individualized baseline data for athletes with LD, ADHD, and high or low levels of cognitive functioning levels because currently there are no comprehensive separate normative baseline data for athletes with these special considerations (Echemendia et al., 2013). This suggests that individualized preseason baseline data is more effective for students with these special considerations than normative baseline data.

Recent research indicates that athletes with LD and ADHD obtain lower scores on neuropsychological assessments and report larger numbers of concussion symptoms than athletes
without these disabilities (Elbin, Kontos, Kegel, Johnson, Burkhart, & Schatz, 2013). A study conducted by Zuckerman, Lee, Odon, Solomon, and Sills (2013) found that young athletes with LD and ADHD earned significantly lower scores on verbal memory, visual memory, and visual motor processing speed measures and significantly higher scores on reaction time measures on a computerized neuropsychological assessment. Additionally, college student athletes who demonstrated high levels of intellectual ability were more likely to show greater post-concussion decline when standardized measures of reading ability were utilized as cognitive baseline data in place of neuropsychological assessment data (Rabinowitz & Arnett, 2012). These results suggest that student athletes who do not receive preseason neuropsychological assessment may appear to exhibit more severe cognitive impairment on post-concussion neuropsychological assessments than is warranted when this type of comparison method is utilized. Results from another study indicate athletes who obtained baseline ImPACT scores that fell either above or below the average range were less likely to be identified as impaired through post-concussion ImPACT assessments when normative baseline data was utilized for pre-test post-test comparisons instead of individualized baseline data (Schatz & Robertshaw, 2014). More specifically, significantly fewer athletes who achieved above average baseline ImPACT scores were found to have sustained substantial cognitive impairment post-concussion. These results suggest that normative baseline data may not accurately represent baseline performances for student athletes who achieve above average ImPACT scores.

The findings from the aforementioned studies highlight the importance of appropriate score comparison methods between baseline and post-concussion neuropsychological assessment scores for student athletes. Specifically, the use of improper baseline scores may misguide clinical decision making and negatively impact the treatment of student athletes with LD,
ADHD, and giftedness who sustain concussions. Taken altogether, these results suggest gaps in current literature. Athletes with these special considerations who are not administered baseline neuropsychological assessments need normative data specific to their population. Although there currently is a lack of inclusive normative data for all student athletes, neuropsychological assessment of concussed athletes has been promoted as an effective aid in managing most brain injuries and is considered an important part of any concussion assessment (Broglio, Macciocchi, & Ferrara, 2007). Student athletes with LD, ADHD, or giftedness must either receive routine preseason neuropsychological assessment or, baseline norms specific to these populations must be created to best treat these student athletes post-concussion.

**Tools.** Neuropsychological assessment helps sports physicians make decisions about concussion management, recovery time, and return to play (McCrory et al., 2013). These tests allow for comprehensive assessment of different cognitive domains and coexisting mental health conditions (Harmon et al., 2013). As a result, traditional paper and pencil neuropsychological testing became a prominent tool in concussion assessment (Collie & Maruff, 2003). Although traditional testing allows a better understanding of sports-related concussions, this type of assessment is often too costly and time-consuming to be implemented by every sport organization across various settings (Randolph, McCrea, & Barr, 2005). More specifically, paper and pencil tests require one-on-one administration and can last for over 30 minutes. More efficient neuropsychological assessment tools are needed to facilitate quick and accurate concussion management (Collie, Darby, & Maruff, 2001). Computerized neuropsychological tests were created to aid in efficient concussion assessment and are now more widely utilized than traditional paper and pencil tests (Broglio, Macciocchi, & Ferrara, 2006). Computerized assessments allow for large numbers of athletes to be tested at the same time, efficient data
scoring and storage, better assessment of reaction time and processing speed, randomization of test stimuli, and quick interpretation of results (Lovell, Collins, & Bradley, 2004). Most computerized neuropsychological assessments measure subtle cognitive domains such as reaction time, visual memory, verbal memory, and processing speed (d’Hemecourt, 2011). These measures of assessment also facilitate appropriate collection of both baseline and post-concussion data in high school and college student athlete populations (Schatz & Zillmer, 2003). Overall, computerized neuropsychological assessment allows for efficient detection and management of cognitive impairment caused by concussion in student athlete populations.

Several computerized assessments have been discussed in literature. The *Immediate Post-Concussion Assessment and Cognitive Testing* (ImPACT) assessment is the most widely used computerized test that measures neurocognitive functioning and concussion symptoms for individuals ages five to 59 (Covassin, Elbin, Stiller-Ostrowski, & Kontos, 2009). More specifically, the ImPACT has been administered in approximately 7,400 different schools and 1,000 colleges (ImPACT Applications, Inc., 2017). Overall, this computerized test measures attention span, verbal and visual memory, working memory, response variability, reaction time, and non-verbal problem solving through six test modules (ImPACT Applications, Inc., n. d.). These modules include word discrimination, design memory, letter location memory, symbol matching, color matching, and letter memory tasks. Five composite scores are generated from responses to items on these test modules and include Verbal Memory, Visual Memory, Visual Motor Speed, Reaction Time, and Impulse Control. Additionally, ImPACT includes a symptom rating scale that assesses the severity of concussion symptoms. Recent research indicates ImPACT effectively detects cognitive changes caused by concussion and is an effective tool for gauging neurocognitive deficits in neuropsychological evaluations (Schatz, Pardini, Lovell,
Collins, & Podell, 2006). Although there are advantages to incorporating neuropsychological testing into concussion assessment batteries, newer neuropsychological testing instruments must continue to be researched and modified (Broglio et al., 2007). Computerized neuropsychological concussion assessment is a relatively new area of research and tests such as the ImPACT must continue to be researched.

Theory Relevant to Research Questions

Cattell-Horn-Carroll (CHC) theory is a multifactor, hierarchical model of cognitive abilities (Hale & Fiorello, 2004) and is considered the most comprehensive and empirically supported psychometric theory of cognitive and academic abilities (Alfonso, Flanagan, & Radwan, 2005). The main aspect of CHC theory assumes that overall cognitive ability is comprised of a combination of a single overarching intelligence construct that encompasses a variety of fluid and crystallized intelligence processes (Hale & Fiorello, 2004). The factors that constitute cognitive intelligence in this theory are most often described as broad and narrow abilities that aid in identifying individual cognitive and academic strengths and weaknesses (Flanagan, Ortiz, & Alfonso, 2013). There are 16 broad abilities and over 80 narrow abilities in the current CHC model (McGrew, 2009). The broad abilities in the current CHC model consist of general, acquired knowledge, and sensory and motor-linked ability domains and include the following: fluid reasoning, short-term memory, long-term storage and retrieval, processing speed, reaction and decision speed, psychomotor speed, comprehension-knowledge, general (domain-specific) knowledge, reading and writing, quantitative knowledge, visual processing, auditory processing, olfactory abilities, tactile abilities, kinesthetic abilities, and psychomotor abilities (Schneider & McGrew, 2012). Overall, CHC theory has an extensive evidence base and aids in the assessment and measurement of broad and narrow cognitive and academic abilities.
The CHC theoretical model aids in closing the gap between theory and practice in the field of psychological test development and interpretation. More specifically, CHC theory helps to classify narrow cognitive abilities as measured by subtests from intelligence test batteries (McGrew, 2009). This type of hierarchical cognitive abilities model has significantly impacted the assessment of cognitive abilities and interpretation of intelligence test performance. As a result, CHC theory is often utilized by intelligence test creators as a theoretical basis for cognitive assessments (Hale & Fiorello, 2004). Most standardized intelligence test batteries assessed for only two or three broad cognitive abilities before the year 1998 (Alfonso et al., 2005). This is a stark contrast to today’s standardized test batteries. Most current intelligence test batteries are developed based on CHC theoretical foundations and measure a range of both broad and narrow abilities (Alfonso et al., 2005). Additionally, most tests today assess for approximately four or five broad cognitive abilities. Cognitive intellectual ability test batteries developed either explicitly or implicitly with principles of CHC theory include versions of the Differential Ability Scales (DAS), Kaufman Assessment Battery for Children (KABC), Wechsler Intelligence Scale for Children, the fifth edition of the Stanford-Binet Intelligence Scales, and every revision of the Woodcock-Johnson Tests of Cognitive Abilities (Keith & Reynolds, 2010). This suggests that CHC theory is a key component of current standardized intelligence test battery development and interpretation.

According to Luria’s Working Brain model, human mental processes are intricate systems that are not localized in specific areas of the brain (Luria, 1973). Instead, mental processes occur throughout interconnected brain structures. Each structure has a unique role in the overall function of the brain however. Luria suggested that the brain is composed of three principle function units (Hale & Fiorello, 2004). The first principle function unit, the reticular
system and its related structures, is mostly accountable for regulating tone and waking and mental states (Languis & Miller, 1992). In other words, this unit is the known as the arousal and attention unit which allows people to concentrate and initiate selective focus of attention (Languis & Miller, 1992). Inadequate functioning of this unit would result in malfunction of the other two units. The second principle function unit includes the occipital, parietal, and temporal lobes of the brain and is primarily responsible for the intake, interpretation, and storage of information (Hale & Fiorello, 2004). This unit is often referred to as the sensory input and integration unit which depends equally on both simultaneous and successive mental coding of experiences (Languis & Miller, 1992). Simultaneous coding pertains to immediate gathering and integrating of various experiences while successive coding refers to sequential integration of experiences into an organized order. The frontal lobes of the brain are considered the third principle function unit and include high-level cognitive activities that manage other low-level cognitive activities (Hale & Fiorello, 2004). Subsequently, this unit is also recognized as the executive planning and organization unit and is considered responsible for impulse control, voluntary action regulation, and linguistic functioning (Languis & Miller 1992). All three of the principle function units in Luria’s Working Brain model are crucial components of overall cognitive functioning.

Each principle function primarily performs notably different cognitive tasks, yet are interdependent on one another to execute activity (Luria, 1973). More specifically, Luria’s model suggests that the brain is a differentiated system whose specialized parts work together for the sake of the unified whole (Luria, 1980). Furthermore, damage to any one principle function typically results in harm to the others (Hale & Fiorello, 2004). This suggests that brain injuries, such as concussions, may disrupt one of the principle function units which will in turn impede
overall brain function. As a result of this significant role in cognitive functioning, Luria’s Working Brain model aids in the development and interpretation of standardized measures of cognitive abilities. This theoretical model has been utilized in the field of psychoeducational assessment in the development of planning, attention, successive processing, and simultaneous processing tasks (Languis & Miller, 1992). Specifically, these tasks developed from Luria’s theory are a part of the Cognitive Assessment System (CAS) which is a standardized measure of cognitive abilities. The development of both editions of the KABC were based largely on aspects of Luria’s theory as well (Keith & Reynolds, 2010). This indicated that Luria’s Working Brain model plays a role in some current standardized intelligence test battery development and interpretation.

The CHC theory assumes that broad and narrow abilities contribute to a single overarching cognitive intellectual ability level much like the three principle function units of the Working Brain model contribute to the overall functioning of the brain. Taken together, CHC theory and Luria’s theoretical model allow for broad and narrow cognitive abilities to be understood as inter-related constructs that impact overall cognitive functioning. Many of the broad and narrow abilities in CHC theory and the cognitive abilities related to the principle function units in Luria’s Working Brain model are cognitive abilities commonly affected by sports-related concussion injuries. Fluid abilities such as memory, attention, working memory, processing speed, and executive functioning are most commonly affected by concussion (Barr & McCrea, 2001; Belanger & Vanderploeg, 2005; Bruce & Echemendia, 2003). All of these abilities are important components of both CHC theory and the Working Brain model, which highlights the need for baseline and post-concussion neuropsychological assessments that efficiently measure these fluid abilities in athlete populations. These concepts provide theoretical
and empirical bases in which the ImPACT can be compared to in order to justify its use as an acceptable neuropsychological assessment for student athletes at-risk for concussion.

As aforementioned, the ImPACT measures attention span, verbal and visual memory, working memory, response variability, reaction time, and non-verbal problem solving through Verbal Memory, Visual Memory, Visual Motor Speed, Reaction Time, and Impulse Control score composites (ImPACT Applications, Inc., n. d.). The cognitive functions assessed through the ImPACT are also broad and narrow abilities in the current CHC model and cognitive abilities found within the principle function units in Luria’s Working Brain model. These cognitive functions are typically impaired by sports-related concussions as well. Overall, this suggests that the ImPACT is an appropriate, empirically supported neuropsychological assessment tool to examine student athlete performance on memory, motor speed, reaction time, and impulse control tasks in the present study.

Barkley’s Extended Phenotypes Theory suggests ADHD is a disorder of executive function and self-regulation, as many symptoms of ADHD are mediated by the prefrontal lobes and can be regarded as executive functions (Barkley, 2015). In this theory, Barkley (2015) argues that executive functions should be viewed within a multilevel hierarchy that “extend outward like a series of concentric rings to impact major domains of human social activity” (p. 419). Barkley proposes that these rings, or levels, build upon one another with each ring laying the foundation for the next and include the following: instrumental – self-directed, methodological – self-reliant, tactical – reciprocal, strategic – cooperative, and extended utilitarian stages of executive functioning as demonstrated in everyday life (Barkley, 2015). Barkley proposes that within the first level, the instrumental – self-directed level, executive functioning is comprised as six forms of actions including self-directed attention, self-restraint,
nonverbal working memory, verbal working memory, self-direction of emotions and motivations, and self-directed play for planning and problem-solving. Within the second level, the methodological – self-reliant level, the instrumental – self-directed executive functions are built upon to facilitate more actions including vicarious learning, social self-defense, and adaptive functioning which consists of time management, self-regulation of emotions, and self-motivation. As the third, tactical-reciprocal level develops, so too do executive functions that allow for engagement in social reciprocity and exchange. This allows for social relationships to develop. The fourth, strategic-cooperative level relies on all the previous levels to develop the ability to accomplish shared goals with others. This ultimately creates the foundation for social groups or communities. All the aforementioned levels build upon one another to develop the final level which allows for people to use culture and other people to consider, plan for, and complete complex actions to accomplish future goals. A deficit in any one or more of the functions in any of these levels, especially within the first foundational level, can result in deficits within the development of the other subsequent levels. This not only results in impairment of the overall hierarchy, but also impairment in significant educational, social, occupational, and other forms of major life functions that rely on adequate executive functioning skills. According to Barkley’s theory, people diagnosed with ADHD are likely to exhibit deficits in executive functioning and self-regulation that impact their overall daily functioning. Taken altogether, people diagnosed with ADHD are likely to display significant deficits in executive functioning and self-regulation on neuropsychological assessment measures. Of particular interest to the current study, Barkley’s Extended Phenotypes Theory provides theoretical rationale for why student athletes diagnosed with ADHD are hypothesized to obtain significantly poorer scores on the composite scores of the ImPACT assessment.
Meltzer and Krishnan (2007) proposed that the following six core executive processes are essential to obtaining adequate performance on complex academic tasks: planning and goal setting, organizing, prioritizing, memorizing, shifting flexibly, self-monitoring and self-checking. Students with learning disabilities often display deficits within these six core executive functions which results in difficulty adequately initiating work, organizing, prioritizing, selecting appropriate goals, shifting strategies, and self-monitoring on academic tasks (Meltzer and Krishnan, 2007). On reading tasks, Meltzer and Krishnan suggest students with learning disabilities may likely to struggle with simultaneously and accurately decoding words, monitoring their performance while tracking text, synthesizing content, and shifting from retrieving prior knowledge to assist in interpreting new content. They also argue that written language tasks may prove challenging for students with learning disabilities as written tasks rely on sufficient initiation, planning, organization, and prioritizing executive functions to independently and appropriately complete the task. Furthermore, Meltzer and Krishnan suggest test taking is another significant challenge for many students with learning disabilities. For example, successful test takers tend to identify the most important information for studying, appropriately allocate their test time, successfully plan their test responses, efficiently monitor themselves throughout the test, and prioritize their test responses. According to Meltzer and Krishnan’s proposal about students with learning disabilities and core executive functions, the academic performance and test taking abilities of students with learning disabilities are likely to be negatively impacted by deficits in the aforementioned six executive functions. Therefore, students with learning disabilities would be expected to obtain significantly poorer scores on the baseline ImPACT composite scores than typically developing or gifted peers.
Recent definitions of giftedness have expanded to include criteria other than high intellectual abilities. The Tripartite Model of Giftedness defines gifted children as exhibiting extraordinary accomplishments in either one or multiple domains that are valued within their culture (Pfeiffer, 2015). This definition allows for broader and more culturally relevant domains of giftedness and talent including art, athletics, academics, leadership, or volunteerism (Pfeiffer, 2015). The Tripartite Model of Giftedness indicates three separate, but complementary ways to identify and assess for gifted and talented students. This includes high intelligence, outstanding accomplishments, and potential to excel (Pfeiffer, 2015). Students can be identified as gifted when they excel within one or more of these three categories. Although these three different categories identify different types and profiles of students with different characteristics and skill sets, these groups may overlap and are not mutually exclusive.

The first category, high intelligence, refers to students who have above average intellectual abilities as commonly assessed through standardized IQ tests, which can include a multidimensional view of intelligence as theorized by Cattell-Horn-Cattell. Students identified within this first category of high intelligence typically earn IQ scores within the top two to five percent when compared to same-aged peers, achieve IQ scores of 135 or higher, and obtain SAT and ACT scores within the top one and two percent of the population (Pfeiffer, 2015). The second category, outstanding accomplishments, are academically gifted learners and tend to perform extraordinarily well on academic assignments and in classroom activities (Pfeiffer, 2015). According to Pfieffer (2015), these students also enjoy learning and academic challenges and are highly motivated in the classroom setting. Students identified within this second category are often identified by their performance in the classroom on academic tasks. The third category, potential to excel, refers to students who are quick learners, hardworking, or highly curious
Students identified within this category are considered students with unusually high potential that is yet unrealized. Pfieffer (2015) specifically refers to these students as “diamonds in the rough.” Overall, gifted students’ academic needs are regularly unmet in the general education classroom, and gifted students often need specialized academic programming or services to best meet their unique needs (Pfieffer, 2015). This suggests that students identified as gifted may perform differently on the baseline ImPACT composites and require separate normative baseline data in the absence of individual baseline data. When considering the Tripartite Model of Giftedness, one might expect students identified as gifted to obtain significantly higher scores on the baseline ImPACT composite scores.

**Current ImPACT Empirical Research**

As aforementioned, normative baseline data may erroneously represent true baseline functioning for athletes with ADHD, LD, and exceptional levels of cognitive abilities or academic achievement (Echemendia et al., 2013). Individual baseline data or specific normative data for students with these special considerations is necessary for appropriate neuropsychological concussion assessment. Athletes with developmental conditions are often excluded from studies utilizing normative samples however (Iverson, Collins, Roberge, Lovell, 2008). This suggests that the use of normative data in place of individual baseline data for athletes with these exceptionalities may lead to inaccurate baseline and post-concussion assessment data comparisons and interpretations. Furthermore, the use of this normative data in these specific populations could potentially lead to improper progress monitoring and treatment of concussion-related impairments. Comprehensive normative data based on the performance of athletes with developmental conditions or exceptionalities on baseline neuropsychological assessments is currently a relatively new and understudied area in sports-related concussion literature. As a result, this area of study must be further researched to ensure appropriate and
accurate neuropsychological assessment of student athletes with LD, ADHD, and exceptional levels of cognitive abilities.

Attention deficit hyperactivity disorder is a neurodevelopmental disorder that causes a persistent pattern of inattentive and/or hyperactive, impulsive behaviors that impact a person’s typical functioning and development (American Psychiatric Association, 2013). These symptoms must be present before the age of 12, observed in at least two different settings, and disrupt social, academic, or occupational functioning. Research suggests that student athletes with ADHD obtain significantly different scores on baseline ImPACT composite scores tasks than students without ADHD. Specifically, Zuckerman, Lee, Odom, Solomon, and Sills (2013) found that athletes with ADHD earned statistically significantly lower scores on the Verbal Memory, Visual Memory, and Visual Motor Speed composites of the ImPACT than athletes without ADHD. The results from this study also revealed that athletes with ADHD demonstrated statistically significantly higher composite scores on Reaction Time and Impulse Control. Similar results were discovered in a study conducted by Elbin, Kontos, Kegel, Johnson, Burkhart, and Schatz (2013). The findings of this study revealed that athletes with ADHD earned statistically lower scores on the ImPACT Verbal Memory, Visual Memory, and Visual Motor Speed composites and statistically higher scores on the Reaction Time composite. Additionally, athletes with ADHD were found to report significantly more physical, emotional, and cognitive post-concussive symptoms than students without disability (Iverson et al., 2015). Overall, student athletes with ADHD have been found to earn significantly different baseline ImPACT scores than student athletes without ADHD. Research on computerized neuropsychological assessment and baseline scores of athletes with various exceptionality statuses is a relatively new
Specific learning disorder is a neurodevelopmental disorder that results in learning difficulties and substantial academic skill deficits that interfere with school or occupational performance or daily living activities (American Psychiatric Association, 2013). These learning difficulties may be innate until specific task demands related to a LD are presented to a person with this disability. Recent studies indicate that student athletes with LD obtain baseline ImPACT scores similar to student athletes with ADHD. More specifically, athletes with LD were found to earn statistically significantly lower Verbal Memory, Visual Memory, and Visual Motor Speed composite scores and statistically significantly higher Reaction Time composite scores on the ImPACT (Zuckerman et al., 2013). Results from a study conducted by Elbin et al. (2013) revealed similar statistically significant differences among the scores athletes with LD earned on the Verbal Memory, Visual Memory, Visual Motor Speed, and Reaction Time composites. Yet another study found that athletes with academic problems demonstrated poorer performance on the Verbal Memory and Processing Speed composites of the ImPACT than athletes without academic problems (Iverson, Collins, Roberge, & Lovell, 2008). More recently, Johnson, Pardini, Sandel, and Lovell (2014) found that student athletes with reading disabilities earned significantly lower scores on the Verbal Memory, Visual Memory, Visual Motor Speed, and Reaction Time composites of the ImPACT. Athletes with LD were also more likely to confirm significantly more physical, emotional, and cognitive post-concussive symptoms than athletes without disability, which is consistent with students with ADHD (Iverson et al., 2015). Similar to athletes with ADHD, students with LD earn statistically significantly different baseline ImPACT scores when compared to students without disability. Again, research in this area of study is a
relatively new and, more research must be conducted with these particular student athlete populations.

Historically, giftedness has been consistently associated with high intellectual abilities by numerous practitioners and students throughout the field of psychology (McClain & Pfeiffer, 2012). More recently however, definitions of giftedness have evolved to include additional criteria. The Tripartite Model of Giftedness explains gifted children as demonstrating “…a greater likelihood, when compared to other students of the same age, experience and opportunity, to achieve extraordinary accomplishments in one or more culturally valued domains” (Pfeiffer, 2015, p. 2). This definition allows for broader, culturally valued domains of extraordinary talent such as art, athletics, academics, leadership, or volunteerism (Pfeiffer, 2015). The Tripartite Model of Giftedness provides three different, yet supplementary ways to identify and assess for academically gifted students which include high intelligence, outstanding accomplishments, and potential to excel (Pfeiffer, 2015). Students can be identified as academically gifted when they fall under one or more of these three categories. This allows a broader conceptualization of giftedness within appropriate cultural context.

In the state of Pennsylvania, gifted students are defined as having outstanding intellectual and creative ability as determined by multidisciplinary evaluations (Pennsylvania Department of Education, 2015). More specifically, a student is identified as gifted if he or she obtains an IQ score at or above 130 or demonstrates exceptional ability in other multiple criteria. These criteria include a year or more above grade level academic achievement for the student’s age group across school subjects, exceptional rates of acquisition and retention of new content or skills, expert achievement in school products, and high level skills in different domains. A student
identified as gifted requires specifically designed school programs or supportive services typically outside the general education classroom.

Currently, very few research studies have directly compared gifted student athletes’ baseline concussion data with typically developing student athletes’ baseline concussion data. However, some research suggests gifted student athletes need separate normative baseline concussion data (Marcotte & Grant, 2009) and urge future research to analyze associations between neuropsychological test score performance and intelligence (Brown, Guskiewicz, & Bleiberg, 2007). A study conducted by Schatz and Robertshaw (2014) found that athletes who obtained baseline ImPACT scores that fell above average were less likely to be identified as impaired through post-concussion ImPACT assessments when normative baseline data was utilized for pre-test post-test comparisons instead of individualized baseline data. Specifically, these athletes were consistently under-classified as impaired when their post-concussive composite scores were compared to standard normative data instead of individualized baseline data. Furthermore, socioeconomic factors such as language and education have been found to influence performance on neuropsychological assessments as well. Specifically, higher levels of education seem to help minimize socioeconomic differences among student athlete test performance (Rabinowitz & Arnett, 2012). Overall, athletes identified as gifted may perform significantly different than typically developing athletes or athletes diagnosed with ADHD or LD. This suggests that gifted students require individual baseline testing or specialized normative data to adequately compare baseline scores with post-concussion scores. No known study to date has directly compared the baseline neuropsychological assessment scores of gifted students to their peers. This is one of the main reasons for the present study.
Current research also suggests that male and female student athletes perform differently on baseline neuropsychological measures. More specifically, female athletes tend to achieve significantly higher scores on baseline verbal memory tasks and lower scores on visual memory tasks than male athletes (Covassin et al., 2006). Results from another study found female athletes performed significantly better than male athletes on the Verbal Memory, Visual Motor Speed, and Reaction Time tasks of the ImPACT (Cottle, Hall, Patel, Barnes, & Ketcham, 2017). Differences exist among male and females on post-concussion neuropsychological assessment scores as well. Females tend to demonstrate greater decline from baseline to post-concussion testing, especially significant decreases in reaction time (Broshek et al., 2005; Colvin et al., 2009). The occurrence of repeated concussion is also related to post-concussion neuropsychological performance between males and females. The results from a study conducted by Covassin, Elbin, Kontos, and Larson (2009) reveal that males with a history of three or more concussions performed worse than females with a history of three or more concussions on verbal memory tasks. Collectively, these findings suggest that differences in scores exist between males and females on both baseline and post-concussion neuropsychological assessment measures. These gender differences will be explored in the present study as well.
CHAPTER III

METHODS

The purpose of the present study is to compare how student athletes with different gender and exceptionality statuses perform on the five baseline ImPACT composite measures and to investigate whether an interaction between gender and exceptionality status exists on these measures. More specifically, this study aimed to determine whether male and female students who identified as typically developing, gifted, or having a diagnosis of LD or ADHD perform differently on the Verbal Memory, Visual Memory, Processing Speed, Reaction Time, and Impulse Control ImPACT baseline composite scores. A discussion of participants’ demographic information is first, followed by detailed descriptions of the ImPACT composite measures. Specific data collection procedures are next explained. Finally, proposed data analyses are provided.

Participants

The sample consisted of a convenience sample of 457 male and female student athletes between the ages of nine and 18 who were enrolled in two different regional Pittsburgh school districts who were administered the baseline ImPACT assessment in group settings as part of completion of routine, preseason sports requirements. A total of 5,762 student athletes’ de-identified information was initially provided to the primary researcher for consideration for participation in the study. After removing participants based on pre-determined exclusionary criteria outlined in the Procedures section, a total of 457 participants remained for analysis.
Measures

The Immediate Post-Concussion Assessment and Cognitive Testing (ImPACT)

The ImPACT is a relatively brief, computerized neuropsychological test that is comprised of six subtests (Lovell, Collins, Podell, Powell, & Maroon, 2000). Participants completed preseason, baseline ImPACT assessment with local athletic trainers, as mandated by their school district. The subtests on the ImPACT measure an athlete’s attention, memory, processing speed, and reaction time (Lovell et al., 2000). The ImPACT Clinical User’s Manual provides an overview of all six modules that comprise the ImPACT. The Word Discrimination and Design Memory modules allow participants to view twelve target words or twelve target designs two times for 750 milliseconds each time. Participants must then recognize and select either the words or designs they saw from a presentation of 24 words that include both target and distractor words and designs. In the Xs and Os module, participants must view a random assortment of Xs and Os for 1.5 seconds. Three target items in this module are highlighted in yellow. Then participants engage in a distractor task which requires them to click the left mouse button when a blue square appears on the computer and the right mouse button when a red circle appears on the screen. Upon completion of the distractor task, the arrangement of Xs and Os appear on the screen and participants are required to identify which items were originally highlighted. The Symbol Matching module requires participants to view nine common symbols that correspond with specific single digit numbers. Participants are then presented with an assortment of symbols and must efficiently click the appropriate corresponding number. In the Color Matching module, participants are required to efficiently click on color words that are printed in their corresponding color ink while ignoring color words printed in mismatched ink. Lastly, the 3 Letters module requires participants to first complete a distractor task that involves clicking a randomized
assortment of numbers in chronologically descending order. Participants are then briefly shown three consonant letters. Immediately following this letter display, participants engage the distractor task again for a total of 18 seconds. They are then asked to recall the three letters they were previously shown. Five overall composite scores are derived from these six modules. More specifically, a person’s performance on the Word Discrimination, Design Memory, Xs and Os, Symbol Matching, Color Matching, and Three Letters modules are used to generate Verbal Memory, Visual Memory, Processing Speed, Reaction Time, and Impulse Control composite scores (ImPACT Applications, Inc., n. d.). Each of these composites assesses different neuropsychological functions.

**Verbal Memory Composite.** The Verbal Memory composite score is comprised of the average of an individual’s total percent correct from the Word Discrimination module, total correct hidden symbols from the Symbol Matching module, and percent of total letters correct from the 3 Letters module (ImPACT Applications, Inc., n. d.). A score in this composite is reported as the percentage correct, with higher scores indicative of better performance (ImPACT Applications, Inc., 2007).

**Visual Memory Composite.** The Visual Memory composite score represents the average of a person’s average total percent correct from the Design Memory module and total correct memory score from the Xs and Os module (ImPACT Applications, Inc., n. d.). The score from this composite is also reported as the percentage correct, with greater scores signifying higher achievement on this measure (ImPACT Applications, Inc., 2007).

**Visual Motor Speed Composite.** The Visual Motor Speed composite score is derived from the average of an individual’s total number correct out of four during the interference of the Xs and Os module as well as the average counted correctly by three from the countdown phase.
of the 3 Letters module. Scores in this composite tend to range from zero to 80, with higher scores indicative of better performance (ImPACT Applications, Inc., 2007).

**Reaction Time Composite.** The Reaction Time composite score represents the average of a person’s average correct reaction time of the interference stage of the Xs and Os module, average correct reaction time out of three in the Symbol Match module, and the average correct reaction time of the Color Match module. The scores from this composite range from zero to one, with lower scores signifying higher achievement on this measure (ImPACT Applications, Inc., 2007).

**Impulse Control Composite.** The Impulse Control composite score is comprised of the total errors on the interference phase of the Xs and Os module and the total commissions from the Color Match module. Scores from this composite typically range from zero to 25, with lower scores indicative of better performance (ImPACT Applications, Inc., 2007). Percentile scores are also calculated in addition to composite scores for performances on the Verbal Memory, Visual Memory, Visual Motor Speed, and Reaction Time modules. All five composite scores were included in the present study.

**ImPACT Composite Score Interpretation.** Normative data analyses for high school male and female students were conducted on a sample of 341 adolescent males and 83 females between the ages of 13 and 18 free with self-reported uncomplicated self-reported medical and educational histories (Lovell & Collins, 2003). Specifically, adolescents with reported histories of receiving special education services, diagnoses of ADHD, or math, reading, or spelling difficulties were excluded from the normative data study. The normative data are based on the natural distribution of scores of 183 males between the ages of 13 and 15, 158 males between the ages of 16 and 18, and 83 females between the ages of 14 and 18 on the Verbal Memory, Visual
Memory, Processing Speed, and Reaction Time composites. These data were used to classify impaired, borderline, low average, average, high average, superior, and very superior score ranges for each age and gender group. The normative tables males between the ages of 13 and 15 and females between the ages of 13 and 18 will be used in the present study to interpret scores on the Verbal Memory, Visual Memory, Processing Speed, and Reaction Time modules. The tables for males and females can be found in Table 1 and Table 2 respectively. As aforementioned, the Impulse Control composite indicates the sums of errors committed during the Xs and Os and Color Match modules of the test. Lower scores on this test are indicative of better performance with scores above 20 considered invalid as a result of possible carelessness or confusion on the modules (ImPACT Applications, Inc., n. d.).

Table 1

Classification Ranges for ImPACT Composite Score Normative Data for Males Ages 13 to 15

<table>
<thead>
<tr>
<th></th>
<th>Verbal Memory</th>
<th>Visual Memory</th>
<th>Processing Speed</th>
<th>Reaction Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Impaired</td>
<td>≤63</td>
<td>≤49</td>
<td>≤16.2</td>
<td>≥.76</td>
</tr>
<tr>
<td>Borderline</td>
<td>64 - 73</td>
<td>50 - 60</td>
<td>16.3 - 24.2</td>
<td>.75 - .67</td>
</tr>
<tr>
<td>Low Average</td>
<td>74 - 79</td>
<td>61 - 68</td>
<td>24.3 - 30.1</td>
<td>.66 - .61</td>
</tr>
<tr>
<td>Average</td>
<td>80 - 92</td>
<td>69 - 86</td>
<td>30.2 - 37.8</td>
<td>.60 - .53</td>
</tr>
<tr>
<td>High Average</td>
<td>93 - 96</td>
<td>87 - 93</td>
<td>37.9 - 44.2</td>
<td>.52 - .49</td>
</tr>
<tr>
<td>Superior</td>
<td>97 - 99</td>
<td>94 - 97</td>
<td>44.3 - 50.2</td>
<td>.48 - .45</td>
</tr>
<tr>
<td>Very Superior</td>
<td>100</td>
<td>98 - 100</td>
<td>≥50.3</td>
<td>≤.44</td>
</tr>
</tbody>
</table>
Table 2

Classification Ranges for ImPACT Composite Score Normative Data for Females Ages 13 to 18

<table>
<thead>
<tr>
<th></th>
<th>Verbal Memory</th>
<th>Visual Memory</th>
<th>Processing Speed</th>
<th>Reaction Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Impaired</td>
<td>≤68</td>
<td>≤49</td>
<td>≤18.9</td>
<td>≥.75</td>
</tr>
<tr>
<td>Borderline</td>
<td>69 - 77</td>
<td>50 - 59</td>
<td>19.0 - 28.9</td>
<td>.74 - .67</td>
</tr>
<tr>
<td>Low Average</td>
<td>78 - 83</td>
<td>60 - 69</td>
<td>29.0 - 32.7</td>
<td>.66 - .61</td>
</tr>
<tr>
<td>Average</td>
<td>84 - 93</td>
<td>70 - 88</td>
<td>32.8 - 42.3</td>
<td>.60 - .51</td>
</tr>
<tr>
<td>High Average</td>
<td>94 - 98</td>
<td>89 - 92</td>
<td>42.4 - 47.0</td>
<td>.50 - .49</td>
</tr>
<tr>
<td>Superior</td>
<td>99 - 100</td>
<td>93 - 98</td>
<td>47.1 - 51.1</td>
<td>.48 - .45</td>
</tr>
<tr>
<td>Very Superior</td>
<td>X</td>
<td>99 - 100</td>
<td>≥51.2</td>
<td>≤.44</td>
</tr>
</tbody>
</table>

ImPACT reliability and validity. Paper-and-pencil neuropsychological concussion test batteries, and their limitations, have been discussed throughout the literature. Conversely, computerized neuropsychological concussion test batteries like the ImPACT aim to overcome traditional paper-and-pencil batteries and are a newer field of research (Collie, Darby, & Maruff, 2001). As a result, reliability and validity data for the ImPACT in sports-related concussion is currently being researched. Findings from studies on the reliability of the ImPACT test are varied. Some studies found the ImPACT to have strong to weak test-retest reliability over time, with greatest reliability for the Processing Speed and Reaction Time composites (Resch et al., 2013). Other literature has established student athlete performance on the ImPACT subtests are correlated with student athlete performance on similar pencil-and-paper tests, specifically on the
Processing Speed and Reaction Time composites (Iverson, Lovell, & Collins, 2005). In a study conducted by Iverson et al. (2003), test-retest reliability for the ImPACT Verbal Memory ($r = 0.70$), Visual Memory ($r = 0.67$), Reaction Time ($r = 0.79$), and Processing Speed ($r = .86$) composites fell within the acceptable and good reliability ranges.

Results from studies on the validity of the ImPACT test are varied as well. The ImPACT yielded the lowest overall percentage of subtest performance of questionable validity out of three widely used computerized neuropsychological tests for baseline performance (Nelson, Pfaller, Rein, & McCrea, 2015). More specifically, the percentage of subtests flagged as being of questionable validity was approximately 3% for the ImPACT, while other computerized neuropsychological tests were both approximately greater than 10% (Nelson et al., 2015). The difference in percentage may be the result of different validity criteria among tests that are sensitive to different types of invalid responses or factors related to the test takers or administrators. Conversely, the ImPACT has validity indicators built into the test that assess for invalid subtest performance. In a study conducted by Erdal (2012), only 11% of all student athletes were able to provide false and invalid responses to subtest items without the ImPACT validity indicators flagging these performances as invalid. Furthermore, the Reaction Time composite serves as an effective indicator of invalid performance because athletes providing fake or invalid response tend to overestimate concussion symptoms (Erdal, 2012). ImPACT validity indicators are effective in flagging invalid performances by student athletes who are both un-coached and coached by others on how to successfully provide fake responses on subtests (Schatz & Glatts, 2013). The findings from these studies suggest that intentional invalid performance on baseline computerized neurocognitive testing can be detected. Additionally, performances on the ImPACT by student athletes aged 10 to 12 years old are more likely to have
a greater proportion of invalid results than performances by student athletes aged 13 to 18 years old (Lichtenstein, Moser, & Schatz, 2014). This suggests the ImPACT may be most effective with older student athlete populations and that younger populations may require more monitored supervision during test administration.

Research Design

Variables

The variables utilized in the present study are gender, exceptionality status, and the five baseline composite scores of the ImPACT (Verbal Memory, Visual Memory, Visual Motor Speed, Reaction Time, and Impulse Control). Gender was defined as male or female student athletes as indicated in the schools’ ImPACT database. Moreover, gender was an independent variable in the current study with two levels: male and female student athletes. As defined by the Pennsylvania Public School Code of 1949 (2 Pa. Code § 1372), exceptional children are children with disabilities and/or children who are gifted and/or talented who are required by law to have access to free and appropriate education (FAPE) that meets their individual and specific needs. According to the Tripartite Model of Giftedness, gifted and/or talented children can be identified by demonstrating high intelligence, outstanding accomplishments, and/or potential to excel (Pfieffer, 2015). Student athletes in the present study were identified as gifted through enrollment in a vetted, high achieving school district. Moreover, the Pennsylvania Code specifically states that students who are identified as gifted and/or talented may meet criteria for exceptional student status. The Code also explicitly states that students identified as having ADHD and LD may also meet criteria for exceptional student status. As a result, student athlete exceptionality status was determined in the present study by student responses to basic demographic questions on the ImPACT and the type of school the student was enrolled in. More
specifically, exceptionality status was an independent variable with three levels: typically
developing students (i.e. control group), students diagnosed with ADHD or LD, and students
identified as gifted. The dependent variables for the present study are the ImPACT baseline
composite scores and were measured by student athletes’ performance on the routinely
administered preseason, baseline ImPACT assessment. More specifically, the dependent
variables include student athletes’ scores on the aforementioned Verbal Memory, Visual
Memory, Processing Speed, Reaction Time, and Impulse Control composites of the ImPACT.

Research Questions 1 and 2 Variables

Independent variables. There are two independent variables for research questions one
and two, and these independent variables are gender and exceptionality status. Gender was a
categorical variable with two levels in which student athletes identified themselves as either male
or female on the basic demographic questions of the ImPACT assessment. Exceptionality status
was a categorical variable with three levels that included typically developing student athletes
(i.e. control group), students diagnosed with ADHD/LD, and students considered to have gifted
status. Student responses to basic demographic questions of the ImPACT and the type of school
the student athletes were enrolled in were utilized to determine placement into the control,
ADHD/LD, and gifted groups. Specifically, student athletes enrolled in the public school district
who reported a history free of any type of mental health, neurodevelopmental, or neurological
disorders were included in the control group. Student athletes who attended either the public
school district or the private college preparatory school district and reported receiving a
diagnosis of either ADHD or LD were then included in the ADHD/LD group. Student athletes
who were enrolled in the high achieving, private college preparatory school district and reported
a history free of any type of mental health, neurodevelopmental, or neurological disorders were included in the gifted group.

**Dependent variables.** For research questions one and two, the five composite scores of the ImPACT served as the dependent variables. Specifically, student athletes’ preseason, baseline Verbal Memory, Visual Memory, Visual Motor Speed, Reaction Time, and Impulse Control composite scores were utilized. All were measured on continuous scales.

**Procedures**

Approval to conduct the present study was obtained from the Institutional Review Board (IRB) at Duquesne University. All participants were recruited from school districts in the local Pittsburgh area. Permission to collect data was obtained from the athletic trainers of each school district. The primary investigator contacted local Pittsburgh school district athletic trainers about the possibility of collecting de-identified information about student athletes’ age, gender, sport type, exceptionality status, and baseline ImPACT composite scores from the school district’s ImPACT database. Permission to collect the aforementioned data was obtained from two Pittsburgh area school districts: one public school district and one private school district. Athletic trainers from both of these districts downloaded student athletes’ ImPACT data into an Excel spreadsheet and then deleted all personally identifying information pertaining to the student athletes from the downloaded spreadsheets (e.g. student athlete identification number, name, date of birth, mailing address, email address, height, and weight). The de-identified spreadsheets were then emailed to the primary research investigator. Data provided by the public school district originally included 901 student athletes assessed every year from 2012 to 2018. The original data set provided to the primary investigator from the private school district included 4,861 student athletes assessed every year from 2009 to 2018. The primary investigator then reviewed the data
sets and removed any extraneous data categories irrelevant to the current study from the de-identified spreadsheets (e.g. sport history questions, all scores other than baseline composite scores, post-concussion treatment questions, symptom questions, medication questions, special education questions).

The researcher then reviewed the dataset and eliminated participants based on predetermined exclusionary criteria. First the researcher removed participants reported to have invalid performance on the baseline ImPACT test (223 total participants) and participants’ post-injury test scores (974 total participants). Then the researcher removed all participants who reported their primary residence was a country other than the United States of America (198 total participants). Participants were also removed if they reported they spoke English as a second language and were administered the English language version of the ImPACT (17 total participants). The researcher then removed any participants who reported a diagnosis of any disabilities other than LD or ADHD, such as Autism Spectrum Disorder, or failed to respond to this question (619 total participants). Repetitive brain trauma, such as multiple concussions, are believed to lead to significant neurocognitive changes over time (Stern et al., 2011). As a result, any student athlete who reported sustaining more than one concussion was excluded from the study (216 total participants). Furthermore, data was only collected from students of all grade levels during the 2017/2018 academic school year to ensure each student athlete’s information was included only once in the study while still allowing a sufficient number of participants to be included in the study (3058 total participants removed). All participants were students involved in contact, limited contact, or noncontact school sports. Even though risk of forceful physical contact and collision is lower in limited-contact sports and noncontact sports, athletes are still able to obtain serious injury by participating in these type of sports (Rice, 2008). As a result,
students participating in all types of sports (e.g. contact, limited contact, and noncontact) were included in the present study. Only information from the following categories of the ImPACT data were included in the present study: age, gender, school, ADHD diagnosis history, LD diagnosis history, sport type, date of test, and baseline ImPACT composite scores. This allowed for the baseline ImPACT composite scores of student athletes identified as typically developing, student athletes diagnosed with LD or ADHD, and student athletes identified as gifted to be analyzed.

**Determining Group Membership**

Exceptionality status was a categorical variable with three levels that included typically developing student athletes (i.e. control group), students diagnosed with ADHD/LD, and students identified as gifted. The ADHD/LD and gifted groups were formed by utilizing student responses to basic demographic questions of the ImPACT as well as the type of school the student athletes were enrolled in. Research suggests that student athletes with ADHD and LD perform similarly on the baseline composite scores (Zuckerman et al., 2013; Elbin et al., 2013). As a result, participants who attended either the public school district or the private school district who reported having a diagnosis of ADHD or LD were expected to achieve similar scores on the baseline ImPACT composites and were combined into one group to form the ADHD/LD group.

The Tripartite Model of Giftedness defines gifted children as exhibiting extraordinary accomplishments in either one or more culturally relevant domains including high intelligence, outstanding accomplishments, and potential to excel (Pfieffer, 2015). Participants in the present study attended one of two schools: an urban public school or a private college preparatory school. Participants who attended the private college preparatory school were required to
successfully pass an admissions test and interview both used to assess each student’s abilities and potential as part of the standard admissions process of the school. Participants who attended this school engaged in academic curriculum that promotes not only academic development, but also physical and emotional development. Specifically, students attending the private college preparatory school had science, technology, engineering, mathematics, humanities and arts, and athletics all as integral parts of their educational curriculum. All participants at this school have the option to join audition-based music ensembles and theatrical productions as well as painting, ceramics, wood and metal work, and architecture classes. These participants also have access to interscholastic, team, and individual sports, both competitive and recreational. Furthermore, middle school participants in this school have access to accelerated sections of mathematics classes while all high school participants’ classes at this school are honors level or higher, with access to Advanced Placement courses and examinations to receive college credit. Participants at this school achieve a 100 percent college matriculation rate, are successfully admitted to several different selective and highly selective colleges and universities around the country, and on average score around the 90th percentile on the SAT and ACT (Shady Side Academy, n. d.). Additionally, more than 75 percent of the faculty teaching at this school held advanced degrees. Taken altogether, participants who attended the private, college preparatory school demonstrate high levels of intelligence, outstanding accomplishments, and potential to exceed, which are the three tenants of The Tripartite Model of Giftedness. As a result, participants who attended this school are considered to be academically talented students as defined by their enrollment in a vetted, high achieving school district and were included in the gifted group of the present study. Any participant who he or she attended the private, college preparatory school and also reported a history free of any type of mental health, neurodevelopmental, or neurological disorders was
included in the gifted group of this study. Student athletes enrolled in the public school district who reported a history free of any type of mental health, neurodevelopmental, or neurological disorders were included in the control group.

**Potential Procedural Limitations**

**Internal Validity**

Internal validity refers to the accuracy of a study in determining the relationship among the independent and dependent variables (Graziano & Raulin, 2013). In other words, internal validity refers to the extent in which the findings of the present study are attributable to the independent variables and are not explained by other factors. The present study utilized a quasi-experimental design known as a causal comparative design to examine ImPACT composite scores among male and female student athletes with different exceptionality statuses. This type of design was utilized because the primary investigator aimed to find relationships between independent and dependent variables after an event, ImPACT assessment, had already occurred. This type of research design does not provide true experimental data because the variables within the study could not be manipulated by the researcher (Cook & Campbell, 1979). No inferences of causation can be made from the findings of the present study.

**External Validity**

External validity refers to the degree to which the results of a study can be generalized to other participants, conditions, times, and places (Graziano & Raulin, 2013). This also refers to the extent to which findings from one study may be replicated with other groups or in other settings. The results of the present study will only be able to be generalized to student athletes in local Pittsburgh school districts who identified themselves either as typically developing persons,
diagnosed with LD, diagnosed with ADHD, or achieving gifted status to maintain external validity.

**Self-Report Data**

As aforementioned, the category variables of gender and exceptionality status were created from information gathered from a brief self-report survey as part of the standardized ImPACT baseline assessment. The basic identifying information collected as part of this self-report may be a potential limitation for the present study because of possible bias from the reporters. Reporters may have answered items incorrectly, misunderstood questions, or chose not to disclose personal information such as history of diagnoses. However, all of this data is kept confidential by athletic trainers in school districts, and student athletes are informed of confidentiality before completing the ImPACT assessment.

**Data Analyses**

The purpose of the present study was to compare how male and female student athletes from the Pittsburgh area with various exceptionality statuses perform on the five baseline ImPACT composite measures. More specifically, research questions one and two of this study investigated gender differences (male and female) and exceptionality statuses (typically developing, diagnosed with ADHD/LD, or gifted) on the Verbal Memory, Visual Memory, Processing Speed, Reaction Time, and Impulse Control baseline ImPACT composites.

An a priori power analysis was completed using G*Power to determine a sufficient sample size (Faul, Erdfelder, Lang, & Buchner, 2007). A power analysis was conducted for a special effects and interactions MANOVA with two predictors (gender and exceptionality status), five groups (male, female, control, ADHD/LD diagnosis, and gifted status), and five dependent variables (Verbal Memory, Visual Memory, Processing Speed, Reaction Time, and
Impulse Control ImPACT composite scores) and using an alpha of 0.05, a power of 0.90, and a medium effect size ($f = 0.25$). Based on the aforementioned assumptions, the desired sample size is at least 47 participants. A MANOVA was used to analyze determine the relationship of gender and exceptionality status on the five baseline ImPACT composite scores. This type of statistical analysis simultaneously examines several dependent variables as well as the interactions between multiple independent variables and ultimately allows for multiple independent variables to be measured by several dependent variables while examining interaction effects among all of the variables (Field, 2014). A MANOVA is the most appropriate statistical analysis for the current study because it assesses group differences among a combination of dimensions with a reduced risk of error as compared to conducting multiple, individual ANOVA analyses (Field, 2014). Specifically, the MANOVA examines the interactions among the two independent variables, and the multiple levels of each independent variable, in the present study with a reduced amount of statistical error.

**Research Questions, Hypotheses, and Statistical Analyses**

**Research Question 1**

Are there differences in baseline ImPACT composite scores earned among student athletes with differing exceptionality statuses?

**Hypothesis 1.** Student athletes diagnosed with ADHD or LD will obtain significantly lower baseline Verbal Memory, Visual Memory, and Visual Motor Speed and significantly higher Reaction Time baseline ImPACT composite scores than student athletes identified as typically developing and gifted.

**Hypothesis 2.** Student athletes identified as gifted will obtain significantly higher baseline Verbal Memory, Visual Memory, and Visual Motor Speed and significantly lower
Reaction Time and Impulse Control ImPACT composite scores than student athletes diagnosed with ADHD or LD and identified as typically developing.

**Statistical Analysis.** A MANOVA was used to analyze determine main and interaction effects of gender (male and female) and exceptionality status (control, diagnosed with ADHD/LD, and gifted) on the five baseline ImPACT composite scores (Verbal Memory, Visual Memory, Visual Motor Speed, Reaction Time, and Impulse Control). This type of analysis was selected to simultaneously examine the relationship of several dependent variables, and their interactions, among multiple independent variables. Alpha values for this analysis were set at $p < 0.05$.

**Research Question 2**

Are there differences in baseline ImPACT composite scores earned among student athletes with differing genders?

**Hypothesis 3.** Female student athletes will obtain significantly higher baseline Verbal Memory and Visual Motor Speed, as well as lower Reaction Time, composite scores than male student athletes.

**Hypothesis 4.** Male student athletes will obtain significantly higher baseline Visual Memory composite scores than female student athletes.

**Statistical Analysis.** A MANOVA was used to analyze determine main and interaction effects of gender (male and female) and exceptionality status (control, diagnosed with ADHD/LD, and gifted) on the five baseline ImPACT composite scores (Verbal Memory, Visual Memory, Visual Motor Speed, Reaction Time, and Impulse Control). This type of analysis was selected to simultaneously examine the relationship of several dependent variables, and their
interactions, among multiple independent variables. Alpha values for this analysis were set at $p < 0.05$. 
CHAPTER IV

RESULTS

The research questions and hypotheses are first reviewed. All relevant participant and variable demographic data and descriptive statistics of the current study are then presented next. Assumptions of the statistical analyses are then reported, including the results of correlations among dependent variables. Finally, MANOVA statistical results of the group differences in gender and exceptionality status among the ImPACT baseline composite scores are presented.

Participant Demographic Information

The software IBM SPSS Statistics version 24 was utilized for all statistical analyses. Out of 457 total participants in the study, 200 (43.8 percent) identified as female and 257 (56.2 percent) identified as male. Seventy-five (16.4 percent) participants self-reported typical development and were included in the Control group. Three hundred fifty (76.6 percent) participants were identified as having achieved gifted status and were included in the Gifted group. Thirty-two (seven percent) self-reported a history of ADHD or LD diagnosis and were included in the Diagnosed with ADHD or LD group. Of all the participants, 370 (81 percent) reported they attended a private college preparatory school in a suburb of Pittsburgh, Pennsylvania, while 87 (19 percent) reported they attended a public, urban school in the city of Pittsburgh, Pennsylvania. The participants’ ages ranged from nine years old to 18 years old, with a mode of 16 years of age. Tables 3 and 4 provide demographic information about all participants.
Table 3

*Frequency Distribution: Entire Sample Demographics*

<table>
<thead>
<tr>
<th>Category</th>
<th>N</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female</td>
<td>200</td>
<td>43.8</td>
</tr>
<tr>
<td>Male</td>
<td>257</td>
<td>56.2</td>
</tr>
<tr>
<td>Typically Developing</td>
<td>75</td>
<td>16.4</td>
</tr>
<tr>
<td>Gifted</td>
<td>350</td>
<td>76.6</td>
</tr>
<tr>
<td>ADHD or LD</td>
<td>32</td>
<td>7</td>
</tr>
<tr>
<td>Private School</td>
<td>370</td>
<td>81</td>
</tr>
<tr>
<td>Public School</td>
<td>87</td>
<td>19</td>
</tr>
<tr>
<td>9 years old</td>
<td>1</td>
<td>0.2</td>
</tr>
<tr>
<td>10 years old</td>
<td>2</td>
<td>0.4</td>
</tr>
<tr>
<td>11 years old</td>
<td>51</td>
<td>11.2</td>
</tr>
<tr>
<td>12 years old</td>
<td>67</td>
<td>14.7</td>
</tr>
<tr>
<td>13 years old</td>
<td>80</td>
<td>17.5</td>
</tr>
<tr>
<td>14 years old</td>
<td>88</td>
<td>19.3</td>
</tr>
<tr>
<td>15 years old</td>
<td>28</td>
<td>6.1</td>
</tr>
<tr>
<td>16 years old</td>
<td>89</td>
<td>19.5</td>
</tr>
<tr>
<td>17 years old</td>
<td>48</td>
<td>10.5</td>
</tr>
<tr>
<td>18 years old</td>
<td>3</td>
<td>0.7</td>
</tr>
</tbody>
</table>
Table 4

*Frequency Distribution: Sample Demographics by Groups*

<table>
<thead>
<tr>
<th>Gender</th>
<th>Exceptionality</th>
<th>Age</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female</td>
<td>ADHD/LD</td>
<td>12</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>14</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>16</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>17</td>
<td>1</td>
</tr>
<tr>
<td>Control</td>
<td></td>
<td>13</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>14</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>15</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>16</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td></td>
<td>17</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>18</td>
<td>1</td>
</tr>
<tr>
<td>Gifted</td>
<td></td>
<td>11</td>
<td>22</td>
</tr>
<tr>
<td></td>
<td></td>
<td>12</td>
<td>29</td>
</tr>
<tr>
<td></td>
<td></td>
<td>13</td>
<td>35</td>
</tr>
<tr>
<td></td>
<td></td>
<td>14</td>
<td>31</td>
</tr>
<tr>
<td></td>
<td></td>
<td>15</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>16</td>
<td>31</td>
</tr>
<tr>
<td></td>
<td></td>
<td>17</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td></td>
<td>18</td>
<td>1</td>
</tr>
<tr>
<td>Male</td>
<td>ADHD/LD</td>
<td>11</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>12</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>13</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>14</td>
<td>4</td>
</tr>
</tbody>
</table>
A total of 34 univariate outliers were present in the data as determined through inspection of boxplots. In large samples however, a small number of outliers is typically expected (Bray & Maxwell, 1985). Since the univariate outliers account for approximately seven percent of the data set, they were kept in and included in the statistical analyses. A total of five multivariate outliers were detected by Mahalanobis distance $\chi^2 (5, N = 457) = 20.52, p < .001$. Multivariate

### Statistical Assumptions
outliers are data points with an unusual combination of values on the dependent variables, and MANOVA is sensitive to these types of outliers (Tabachnik & Fidell, 2014). As a result, all five multivariate outliers were removed from the data set and excluded from the following statistical analyses. The assumption of homogeneity of covariance was met, as assessed by Box’ M test ($p = .356$) and shown in Table 5.

Table 5

*Box’s Test of Equality of Covariance Matrices*

<table>
<thead>
<tr>
<th></th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Box’s M</td>
<td>91.599</td>
</tr>
<tr>
<td>F Statistic</td>
<td>1.054</td>
</tr>
<tr>
<td>Degrees of Freedom 1</td>
<td>75</td>
</tr>
<tr>
<td>Degrees of Freedom 2</td>
<td>2691.707</td>
</tr>
<tr>
<td>Significance</td>
<td>0.356</td>
</tr>
</tbody>
</table>

The assumption of homogeneity of variance was also met for the five baseline composite scores of the ImPACT (Verbal Memory Composite, Visual Memory Composite, Visual Motor Speed Composite, Reaction Time Composite, and Impulse Control Composite) for all group combinations of gender and exceptionality status as determined by Levene’s test for equality of variances ($p > .05$), therefore the variances of these variables were equal among the groups (see Table 6). The Levene’s Test was based on median scores, as the median is the most appropriate for data with skewed distributions (Brown & Forsythe, 1974).
Table 6

Levene’s Test of Equality of Error Variances among the ImPACT Baseline Composite Scores Based on Median

<table>
<thead>
<tr>
<th></th>
<th>Levene Statistic</th>
<th>Degrees of Freedom 1</th>
<th>Degrees of Freedom 2</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Verbal Memory</td>
<td>0.956</td>
<td>5</td>
<td>451</td>
<td>0.445</td>
</tr>
<tr>
<td>Visual Memory</td>
<td>0.473</td>
<td>5</td>
<td>451</td>
<td>0.796</td>
</tr>
<tr>
<td>Visual Motor</td>
<td>0.519</td>
<td>5</td>
<td>451</td>
<td>0.762</td>
</tr>
<tr>
<td>Reaction Time</td>
<td>1.583</td>
<td>5</td>
<td>451</td>
<td>0.164</td>
</tr>
<tr>
<td>Impulse Control</td>
<td>1.139</td>
<td>5</td>
<td>451</td>
<td>0.339</td>
</tr>
</tbody>
</table>

Moderate correlations among the dependent variables were detected using Pearson’s correlation (see Table 7), which indicates MANOVA was an appropriate analysis to conduct. The only exception was the correlation between the Reaction Time and Impulse Control Composite scores were found to be weakly correlated ($p = .042$). This is a potential limitation within the current study. Although Shapiro-Wilk tests of normality revealed non-normal distributions of data as shown in Table 8, Bray and Maxwell (1985) indicate MANOVA is fairly robust to deviations from normality.

Table 7

Pearson Correlations among the ImPACT Baseline Composite Scores

<table>
<thead>
<tr>
<th></th>
<th>Verbal Memory</th>
<th>Visual Memory</th>
<th>Visual Motor</th>
<th>Reaction Time</th>
<th>Impulse Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Verbal Memory</td>
<td>-</td>
<td>.465</td>
<td>.367</td>
<td>-.278</td>
<td>-.124</td>
</tr>
<tr>
<td>Visual Memory</td>
<td>.465</td>
<td>-</td>
<td>.389</td>
<td>-3.22</td>
<td>-2.32</td>
</tr>
<tr>
<td></td>
<td>Control Group</td>
<td>Gifted Group</td>
<td>ADHD/LD Group</td>
<td></td>
<td></td>
</tr>
<tr>
<td>----------------------------------</td>
<td>---------------</td>
<td>--------------</td>
<td>---------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>Male</td>
<td>Female</td>
<td>Male</td>
<td>Female</td>
</tr>
<tr>
<td>Test Statistic (Verbal Memory)</td>
<td>0.926</td>
<td>0.941</td>
<td>0.930</td>
<td>0.917</td>
<td>0.849</td>
</tr>
<tr>
<td>( p ) Value</td>
<td>0.048</td>
<td>0.020</td>
<td>0.000</td>
<td>0.000</td>
<td>0.156</td>
</tr>
<tr>
<td>Test Statistic (Visual Memory)</td>
<td>0.973</td>
<td>0.967</td>
<td>0.972</td>
<td>0.965</td>
<td>0.903</td>
</tr>
<tr>
<td>( p ) Value</td>
<td>0.662</td>
<td>0.203</td>
<td>0.000</td>
<td>0.000</td>
<td>0.393</td>
</tr>
<tr>
<td>Test Statistic (Visual Motor)</td>
<td>0.966</td>
<td>0.949</td>
<td>0.979</td>
<td>0.967</td>
<td>0.958</td>
</tr>
<tr>
<td>( p ) Value</td>
<td>0.478</td>
<td>0.041</td>
<td>0.013</td>
<td>0.000</td>
<td>0.808</td>
</tr>
<tr>
<td>Test Statistic (Reaction Time)</td>
<td>0.957</td>
<td>0.944</td>
<td>0.927</td>
<td>0.992</td>
<td>0.934</td>
</tr>
<tr>
<td>( p ) Value</td>
<td>0.294</td>
<td>0.026</td>
<td>0.000</td>
<td>0.395</td>
<td>0.614</td>
</tr>
<tr>
<td>Test Statistic (Impulse Control)</td>
<td>0.947</td>
<td>0.882</td>
<td>0.919</td>
<td>0.929</td>
<td>0.908</td>
</tr>
<tr>
<td>( p ) Value</td>
<td>0.163</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.425</td>
</tr>
</tbody>
</table>

Table 8

*Shapiro-Wilk Tests of Normality*
Analysis of Research Questions 1 and 2

Research questions one and two investigated the impact of gender (male and female) and exceptionality status (Control, Gifted, and Diagnosed with ADHD or LD) among the ImPACT baseline composite scores (Verbal Memory, Visual Memory, Visual Motor Speed, Reaction Time, and Impulse Control). A two-way MANOVA was conducted to determine the effects of gender and exceptionality status on the five ImPACT baseline composite scores. A significant difference was found among exceptionality statuses on the dependent variables, Wilks’ $\lambda = .94$, $F(10, 894) = 2.83, p = .002, \eta^2 = .031$. No significant difference was found with gender on the dependent variables, Wilks’ $\lambda = .98$, $F(5, 447) = 1.94, p = .087, \eta^2 = .021$. Additionally, no significant interaction effect was found among gender and exceptionality status on the dependent variables, Wilks’ $\lambda = .97$, $F(10, 894) = 1.30, p = .228, \eta^2 = .014$. The means and standard deviations of gender and exceptionality status on the dependent variables are presented in Table 9 and the results of the MANOVA are shown in Table 10.

Table 9

Means and Standard Deviations of Gender and Exceptionality Status on the Dependent Variables

<table>
<thead>
<tr>
<th>Gender</th>
<th>Verbal Memory</th>
<th>Visual Memory</th>
<th>Visual Motor</th>
<th>Reaction Time</th>
<th>Impulse Control</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
<td>M</td>
<td>SD</td>
<td>M</td>
</tr>
<tr>
<td>Female</td>
<td>88.50</td>
<td>1.58</td>
<td>76.28</td>
<td>1.97</td>
<td>37.30</td>
</tr>
<tr>
<td>Male</td>
<td>84.65</td>
<td>0.89</td>
<td>76.28</td>
<td>1.10</td>
<td>34.65</td>
</tr>
<tr>
<td>Status</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>83.69</td>
<td>1.24</td>
<td>72.47</td>
<td>1.54</td>
<td>35.86</td>
</tr>
<tr>
<td>ADHD/LD</td>
<td>88.46</td>
<td>2.36</td>
<td>77.76</td>
<td>2.92</td>
<td>34.51</td>
</tr>
<tr>
<td>Gifted</td>
<td>87.58</td>
<td>0.56</td>
<td>79.38</td>
<td>0.69</td>
<td>37.56</td>
</tr>
</tbody>
</table>
Table 10

*Multivariate Test Results, Wilks Lambda Distribution*

<table>
<thead>
<tr>
<th></th>
<th>Value</th>
<th>F</th>
<th>Hypothesis df</th>
<th>Error df</th>
<th>p Value</th>
<th>Partial η²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td>0.979</td>
<td>1.939</td>
<td>5</td>
<td>447</td>
<td>0.087</td>
<td>0.021</td>
</tr>
<tr>
<td>Exceptionality Status</td>
<td>0.940</td>
<td>2.833</td>
<td>10</td>
<td>894</td>
<td>0.002</td>
<td>0.031</td>
</tr>
<tr>
<td>Interaction</td>
<td>0.972</td>
<td>1.297</td>
<td>10</td>
<td>894</td>
<td>0.228</td>
<td>0.014</td>
</tr>
</tbody>
</table>

Analyses of variance (ANOVA) on the dependent variables were conducted as follow-up tests to the MANOVA. Statistically significant differences of exceptionality status were found on the Verbal Memory Composite Score, $F(2, 451) = 4.28, p = .014, \eta^2 = .019$, and the Visual Memory Composite Score, $F(2, 451) = 8.395, p < .000, \eta^2 = .036$. No significant differences of exceptionality status were found on the Visual Motor Speed Composite Score, $F(2, 451) = 2.92, p = .055, \eta^2 = .013$, Reaction Time Composite Score, $F(2, 451) = 2.59, p = .076, \eta^2 = .011$, or Impulse Control Composite Score, $F(2, 451) = 0.83, p = .453, \eta^2 = .004$. The results of the ANOVA are presented in Table 11.

Table 11

*Tests of Between-Subjects Results for Exceptionality Status*

<table>
<thead>
<tr>
<th></th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>p Value</th>
<th>Partial η²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Verbal Memory</td>
<td>2</td>
<td>463.529</td>
<td>4.280</td>
<td>0.014</td>
<td>0.019</td>
</tr>
<tr>
<td>Visual Memory</td>
<td>2</td>
<td>1399.470</td>
<td>8.395</td>
<td>0.000</td>
<td>0.036</td>
</tr>
<tr>
<td>Visual Motor</td>
<td>2</td>
<td>155.352</td>
<td>2.915</td>
<td>0.055</td>
<td>0.013</td>
</tr>
<tr>
<td>Reaction Time</td>
<td>2</td>
<td>0.019</td>
<td>2.588</td>
<td>0.076</td>
<td>0.011</td>
</tr>
<tr>
<td>Impulse Control</td>
<td>2</td>
<td>16.761</td>
<td>0.833</td>
<td>0.435</td>
<td>0.004</td>
</tr>
</tbody>
</table>
Post hoc analyses to the ANOVA for the ImPACT scores consisted of conducting Bonferroni pairwise comparisons to find which exceptionality statuses affected performance on the ImPACT composite scores most strongly. There was a statistically significant mean difference between the Gifted and Control groups, $p = .005$, on the Verbal Memory Composite Score, with members of the Gifted group earning significantly higher scores than members of the Control group. A statistically significant mean difference was also found between the Gifted and Control groups on the Visual Memory Composite Score, $p < .000$, with the members of the Gifted group achieving significantly better scores than members of the Control group.

**Summary**

The results obtained from the analyses conducted for the present study yielded several important findings. Analyses investigating the effects of gender and exceptionality status on the five ImPACT composite scores revealed significant main effects of exceptionality status, while main effects of gender and interaction effects were not statistically significant. Follow-up analyses revealed members of the Gifted group obtained significantly higher scores than members of the Control group on the Verbal Memory Composite Score and the Visual Memory Composite Score.
CHAPTER V

DISCUSSION

Summary

The *Immediate Post-Concussion Assessment and Cognitive Testing* (ImPACT) assessment is one of the most widely used computerized tests that measures neurocognitive functioning and concussion symptoms (Covassin, Elbin, Stiller-Ostrowski, & Kontos, 2009). Research suggests the ImPACT effectively detects cognitive changes caused by concussion and is an effective tool for gauging neurocognitive deficits in neuropsychological evaluations (Schatz et al., 2006). Normative data may be utilized for pre-concussion assessment if a student athlete was not administered a preseason baseline assessment before acquiring a concussion (Doolan, Day, Maerlender, Goforth, & Brolinson, 2011). At the inception of this study, however, this normative data was based on typical baseline test scores obtained from the general population of student athletes. As a result, the use of this normative data may allow for student athletes with preexisting learning disabilities (LD), attention deficit hyperactivity disorder (ADHD), and giftedness to be inaccurately represented in normative baseline scores (Grindel, Lovell, & Collins, 2001). This suggests individualized baseline data for athletes with LD, ADHD, and giftedness may be a better indicator of pre-injury cognitive functioning than current normative baseline data if these populations score differently on the baseline ImPACT composites (Echemendia, et al., 2013).

The present study investigated whether students with LD or ADHD status, gifted status (i.e., vetted high academically achieving student), and control status performed differently on the five composite scores of the ImPACT. As explained earlier, participants assigned to the gifted status group included students who attended a private college preparatory school, with
established vetting procedures, for academically talented children. Research questions one and two investigated whether a relationship existed between gender (male and female) and exceptionality status (i.e., control, ADHD/LD, and gifted) on the five baseline composite scores of the ImPACT (Verbal Memory, Visual Memory, Visual Motor Speed, Reaction Time, and Impulse Control). It was hypothesized that student athletes diagnosed with ADHD or LD would obtain significantly lower baseline Verbal Memory, Visual Memory, and Visual Motor Speed, and significantly higher Reaction Time baseline ImPACT composite scores than student athletes identified as typical controls and of gifted status. On the other hand, student athletes identified as gifted would earn significantly higher baseline Verbal Memory, Visual Memory, and Visual Motor Speed and significantly lower Reaction Time and Impulse Control ImPACT composite scores than student athletes diagnosed with ADHD or LD and identified as typically developing.

It was also hypothesized that female student athletes would obtain significantly higher baseline Verbal Memory and Visual Motor Speed, as well as lower Reaction Time, composite scores than male student athletes; whereas male student athletes would earn significantly higher baseline Visual Memory composite scores than female student athletes. The findings of the present study revealed significant main effects of exceptionality status, while main effects of gender and interaction effects were not statistically significant. Follow-up analyses revealed members of the Gifted group obtained significantly higher scores than members of the Control group on the Verbal Memory Composite Score and the Visual Memory Composite Score.

**Conclusions Regarding Exceptionality Status**

Results from previous studies indicate that student athletes with ADHD obtain significantly different scores on baseline ImPACT composite scores tasks than students without ADHD. In particular, student athletes with ADHD earned significantly lower scores on the
Verbal Memory, Visual Memory, and Visual Motor Speed baseline ImPACT composites and significantly higher scores on Reaction Time and Impulse Control baseline ImPACT composites (Zuckerman et al., 2013). Similar results were discovered in another study that found athletes with ADHD earned lower scores on the ImPACT Verbal Memory, Visual Memory, and Visual Motor Speed composites and higher scores on the Reaction Time composite (Elbin, et al., 2013). Other studies suggest student athletes with LD obtain baseline ImPACT scores similar to student athletes with ADHD. For example, athletes with LD were found to earn statistically significantly lower Verbal Memory, Visual Memory, and Visual Motor Speed composite scores and statistically significantly higher Reaction Time composite scores on the ImPACT (Elbin, et al., 2013; Johnson et al., 2014; Zuckerman, et al., 2013). Contrary to the results from the aforementioned studies, no significant differences were found in the present study among student athletes with ADHD/LD when compared to the control and gifted groups.

At present, no known study has directly compared the baseline neuropsychological assessment scores of gifted students to their peers. This was a primary emphasis of this study and inclusion to the empirical literature. Additionally, very few research studies have discussed giftedness and student athletes’ baseline concussion data. Answering this research question was important as some studies suggest gifted student athletes need separate normative baseline concussion data (e.g., Marcotte & Grant, 2009) and still others urge future research to analyze associations between neuropsychological test score performance and intelligence (Brown, Guskiewicz, & Bleiberg, 2007). In fact, an empirical investigation found that athletes who obtained baseline ImPACT scores that fell above average were less likely to be identified as impaired through post-concussion ImPACT assessments when normative baseline data was utilized for pre-test post-test comparisons as compared to when individualized baseline data were
used (Schatz & Robertshaw, 2014). Specifically, these athletes were consistently under-classified as impaired when their post-concussive composite scores were compared to standard normative data instead of individualized baseline data. The present study did find some significant scores differences among some, but not all, of the baseline ImPACT composite scores for student athletes identified as gifted when compared to their peers.

The current study found statistically significant differences between the gifted and control groups on the Verbal Memory Composite Score and the Visual Memory Composite Score, with members of the gifted group earning significantly higher scores than members of the control group. No significant differences were found between these groups on the remaining baseline ImPACT composite scores (Visual Motor Speed, Reaction Time, and Impulse Control). Furthermore, no significant differences were discovered between the gifted and ADHD/LD group or the ADHD/LD and control group on any of the baseline ImPACT composite scores. A review of a test of visual-motor integration indicates that performance on visual motor tasks is only moderately correlated with performance on tests of intelligence (Beery & Beery, 2004) and may help explain the nonsignificant results on the Visual Motor Speed composite of the present study. It is worth noting that the significance value of the Visual Motor Speed composite for exceptionality status was close to the cut-off value ($p = 0.55$). Also remarkable is the fact that even though the gifted group earned statistically significantly higher scores on the Verbal Memory and Visual Memory composites as compared to control athletes, the mean scores earned by the gifted group for both of these composites fell in the Average according to the ImPACT’s Classification Ranges for ImPACT Composite Score Normative Data for males and females ages 13 to 18.
The finding that participants with gifted status earned higher scores on the Verbal Memory and Visual Memory than participants in the control group may be expected as cognitive abilities have historically been a central feature of giftedness throughout previous research studies (Feldman, 1986; Gallagher, 2008; Humphreys, 1985; Stanley, 2000). Given existing literature, it might be expected that participants in the gifted group would obtain higher scores on the ImPACT composites than participants in the ADHD/LD group as well. In particular, one study found that typically developing children earned higher scores than children with reading and math impairments on assessment measures of sustained attention, vocabulary, verbal paired associate learning, and visual motor skills (Shaywitz, 2004). Results from yet another study revealed that typically developing children obtained better scores than children with reading disabilities, math disabilities, and ADHD on sustained attention, vocabulary, and verbal paired associate learning assessment tasks (Fletcher, 2005). The findings from the present study are seemingly inconsistent with previous studies in that the gifted group did not perform significantly better than the ADHD/LD group on the baseline composite scores.

Also unexpected was that the ADHD/LD group actually earned similar scores as the gifted group on the Verbal Memory composite of the ImPACT. One possible explanation for these findings is that in the studies mentioned above, assessment measures were administered individually to each participant while all participants in the present study were administered the baseline ImPACT in group settings. One study found that neurocognitive skills are vulnerable to distractions in test environments, and individuals earned significantly better ImPACT composite scores when administered the ImPACT individually than individuals who were administered the ImPACT in a group study (Moser, Schatz, Neidzwski, & Ott, 2011). In particular, this study found that participants who were administered the ImPACT in the group setting achieved
significantly lower Verbal Memory, Visual Memory, Visual Motor Speed, and Reaction Time scores than participants who were administered the ImPACT individually. These results suggest the lack of a quiet, standardized, individualized setting in the current study may have negatively impacted participants’ ImPACT performance.

Although the insignificant findings between the gifted group and ADHD/LD group, and then the ADHD/LD group and control group were inconsistent with the aforementioned studies, there are other studies that may help to better explain the obtained results. In particular, there are studies that investigate go/no-go tasks that measure response inhibition by requiring individuals to respond to specific stimuli (i.e., “go”) and make no response for other stimuli (i.e., “no-go”). These tasks are measured by the commission error rate which involves tracking how many responses individuals make when they are supposed to be refraining from responding. The *Conners Continuous Performance Test* (CPT, Conners, 2000) is a type of go/no-go task that purports to measures attention, impulsivity, sustained attention, and vigilance. Studies evaluating the effectiveness of go/no-go tasks, and particularly the Conners CPT, in identifying individuals with ADHD have found that these measures have an approximately 50% error rate in differentiating individuals with ADHD and controls (McGee, Clark, & Symons, 2000; Halperin et al., 1990). Other studies found similar inconsistencies in successful identification of attention problems in individuals with ADHD on the CPT (Corkum & Segal, 1993; Trommer, Hoeppner, Lorber, & Armstrong, 1988) and other types of computerized tests of attention (Koelega, 1995). Given that the Reaction Time and Impulse Control composite scores are comprised of scores from go/no-go tasks of the ImPACT, these CPT studies may explain why there were no significant differences among student athletes with ADHD and the two other groups on the Reaction Time and Impulse Control composite.
Overall, the findings of the present study reveal participants identified as gifted earned significantly higher scores than controls in verbal and visual memory tasks, which is to be expected. There were no significant findings regarding the ADHD/LD group’s scores when compared to the gifted and control groups, which was unexpected. However, there are a number of limitations regarding the ADHD/LD group which will be outlined in the limitations section of this chapter.

Conclusions Regarding Gender

Research suggests that male and female student athletes perform differently on baseline neuropsychological measures as previous investigations have found female athletes achieve significantly higher scores on baseline verbal memory tasks and lower scores on visual memory tasks than male athletes (Covassin, et al., 2006). Another study found female athletes performed significantly better than male athletes on the Verbal Memory, Visual Motor Speed, and Reaction Time tasks of the ImPACT (Cottle, et al., 2017). Contrary to the results of previous research, the present study did not find any significant difference between male and female performance on the five baseline ImPACT composite scores. The findings of this study suggest males and females earn similar baseline composite scores of the ImPACT. One possible explanation for these differences is that the aforementioned studies that found gender differences in baseline neuropsychological measures were among college students. The present study examined gender differences among students between the ages of nine and 18. Some studies have found that childhood and adolescence are periods of brain growth and change (Giedd, et al., 1999) and executive functions such as planning, working memory, and impulse control are some of the last areas of the brain to mature (Sowell, Thompson, Holmes, Jernigan, & Toga, 1999). Specifically, these executive functions may not be fully developed until later in life. This suggests the findings
of the present study are likely as result of the age and neuropsychological maturation of the participants.

**Study Limitations**

Response bias refers to conditions or factors that take place during participants’ completion of surveys or questions and impact the way their responses are provided (Lavrakas, 2008). This can occur for many reasons, two of which include a simple misunderstanding of the self-report or a desire to underreport information in attempt to be viewed favorably even if the self-report is anonymous (Lavrakas, 2008). One limitation to the current study is that the self-report information utilized to create the control and ADHD/LD groups was collected from student athletes between the ages of nine and 18. It is possible participants could have provided factually incorrect responses due to misinterpretation of questions or a purposeful attempt to deny the presence of a disability. The Hawthorne effect suggests participants’ behaviors and responses within a research study may be influenced when observed by others (McCambridge, Witton, & Elbourne, 2014). This concept is potentially another limitation within the present study. Student athletes in the current study were administered the ImPACT in a group setting with similar aged peers, as well as an athletic trainer, present in the room. The presence of others in the room during ImPACT administration may have negatively impacted students’ self-report answers, effort on administered tasks, and overall performance on the ImPACT.

Recent studies suggest student athletes with ADHD obtain similar baseline ImPACT scores as student athletes with LD. In particular, athletes with ADHD and LD were found to earn statistically significantly lower Verbal Memory, Visual Memory, and Visual Motor Speed composite scores and statistically significantly higher Reaction Time composite scores on the ImPACT than typically developing peers (Zuckerman, et al., 2013; Kontos, et al., 2013). These
findings were not replicated in the present study, which might be the result of study limitations. The combination of student athletes with ADHD and LD into one categorical group is a limitation of the study. Although other studies have found student athletes with diagnoses of ADHD and LD perform similarly on the ImPACT, ADHD and LD are two distinct and separate disorders. Students with these disorders could be categorized into two separate groups rather than one. Another major limitation within the ADHD/LD group is the small sample size. Taken together, the combination of student athletes with ADHD and LD, as well as the small sample size of this group, is a major limitation to the study.

Student athletes with multiple concussions were excluded from the present study because multiple concussions have been found to lead to significant neurocognitive changes over time (Stern et al., 2011). Although students who reported sustaining multiple concussion were excluded, student athletes who reported a history of one concussion remained as participants in the study. This is a limitation that may be considered for future research. Another limitation to the present study is the gifted group solely relied on participants’ enrollment into a private, college preparatory school district vetted to have academically high achieving students to determine gifted status. Overall, the lack of verification of exceptionality status for the ADHD/LD and gifted groups by either school personnel, medical providers, mental health professionals, or other qualified personnel presents as a major limitation to the current study as participants’ placement into either the control, ADHD/LD, and gifted groups could change based on verification from a qualified person.

The ImPACT assessment included children ages nine to 18. Although the ImPACT assessment administered to children ages five to 11 includes the same tasks and composite scores as the ImPACT assessment administered to children ages 12 and up, the administration time for
the younger children is less to ensure the tasks are developmentally appropriate (ImPACT, 2019). In particular, the ImPACT administered to children ages five to 11 takes approximately 10 to 15 minutes to complete, whereas the ImPACT administered to children ages 12 and up takes approximately 25 minutes to complete. These differences in administration time may impact the performance of participants when considering the negative impact group neuropsychological assessment administration has on an individual’s performance. In other words, older student athletes who spend more time completing the ImPACT assessment are more at risk for group setting effects. These older students typically spend a longer period of time completing the ImPACT assessment, which causes them to remain in the assessment room for a longer. As a result, the participants administered the ImPACT in a group setting have longer exposure to unstandardized and uncontrolled assessment environments that may include distractions from the assessment and can confound the findings of the present study. The time variation, although developmentally appropriate for children of various ages, is a limitation within the current study when also considering group administration.

The current study utilized a quasi-experimental design, particularly a causal comparative design, to investigate the relationship among exceptionality status and gender on the five baseline ImPACT composite scores. A causal comparative design was utilized to find relationships between independent and dependent variables after an event has already occurred (Cook & Campbell, 1979). In particular, the present study aimed to determine whether gender or exceptionality status affected pre-existing student athlete ImPACT scores. This type of research design does not provide true experimental data because the variables within the study could not be manipulated by the researcher, which is a limitation within the present study. In particular, group membership of students placed in exceptionality status categories could not be verified.
Overall, the present research design lacks internal validity and no inferences of causation can be made from the findings of this study. Another limitation within the present study is the extent in which the findings are able to be generalized to other populations. The generalizability of this study is impacted by the homogeneity of the sample. Specifically, all participants were students enrolled in one of two school districts within the same geographical area. Additionally, the number of students who reported having a diagnosis of ADHD/LD was small. It may be likely that different results would be found if a larger number of participants with a diagnosis of ADHD/LD was included.

**Recommendations for Future Research**

As discussed throughout this chapter, the current study had several limitations that should be considered and addressed for future research. The first recommendation for future studies is to separate participants with ADHD or LD into two distinct groups. In the present study, students with ADHD or LD were combined into one group because of a few research studies that suggest students with these disorders perform similarly to one another on the baseline ImPACT composite scores (Zuckerman, et al., 2013; Kontos, et al., 2013). Although these populations may achieve comparable scores on the ImPACT composites, they are two distinctly separate populations each with specifically different symptoms. As a result, future studies should create separate groups for participants with ADHD or LD. Another consideration for future studies is to have a larger sample size, particularly for participants with ADHD or LD. The current study had significantly less participants with ADHD or LD when compared to participants who were identified as gifted or participants as part of the control group.

A third recommendation for future studies would be to collect data from multiple schools in more than one geographical area. In the present study, data was only gathered from two school
districts within the same geographical region. Collecting data from more school districts in various locations across the country could increase external validity and make results more generalizable. Furthermore, student athlete exceptionality status should be verified by school personnel, medical providers, mental health professionals, or other qualified personnel to obtain internal validity in future studies. As previously mentioned, each student’s individual exceptionality status has the potential to change with verification from qualified personnel which is a major limitation of the present study. Another recommendation for future studies would be to gather data from individually administered baseline ImPACT assessments. The current study utilized data from group administered assessments, and research suggests individuals perform best when provided with individual, standardized, and controlled assessment administration (Moser et al., 2011). Lastly, future studies might examine children ages five to 11 and children ages 12 and up separately. Although the tasks administered as part of the ImPACT assessment for both of these age groups are the same and the same five composite scores are produced as a result of performance on these tasks, it might be of interest for future studies to examine the groups separately.

**Implications**

As aforementioned, the ImPACT has been found to effectively detect cognitive changes caused by concussion and is regularly utilized as an effective tool for gauging neurocognitive deficits (Schatz et al., 2006). Scores from normative databases can, and have been, used in place of individual baseline scores when a student athlete does not have valid individual preseason baseline data on file after sustaining a concussion (Doolan et al., 2011). Use of these normative data for student athletes with preexisting learning disabilities (LD), attention deficit hyperactivity disorder (ADHD), and giftedness may cause them to be inaccurately assessed post-concussion as
students with these exceptionality statuses are largely excluded from most normative datasets (Grindel, Lovell, & Collins, 2001). In particular, student athletes with ADHD or LD would be expected to earn poorer scores than typically developing student athletes on some composites on the ImPACT. If normative data were used in place of individualized baseline scores for students with ADHD or LD, then students with these exceptionality statuses may appear inaccurately more severely impaired on both immediate and subsequent post-concussion assessments than is actually warranted. Similarly, students identified as gifted would be expected to earn better ImPACT composite scores than typically developing student athletes. Normative data utilized in place of preseason baseline data for gifted and/or talented students may then cause their functioning to erroneously appear unimpaired by the concussion when their functioning is in fact impaired. Overall this suggests individualized baseline data is a necessity for student athletes with exceptionality statuses such as LD, ADHD, and giftedness to provide appropriate immediate and follow-up post-concussion assessment and treatment.

Summary

The present study sought to investigate whether there were any significant differences among student athletes with ADHD, LD, or giftedness among the baseline ImPACT composite scores when compared to typically developing student athletes. The main reason for investigating this topic was to advocate for student athletes with these exceptionality statuses to either receive individualized, baseline concussion assessment or to have normative data specific to these populations created to be utilized in the event students with these exceptionality statuses had no baseline concussion assessment data on file to compare to post-concussion assessment data. Although the results of the current study must be interpreted with caution because of lack of internal validity, the findings of this study suggest there may be differences in baseline scores
among students identified as gifted when compared to typically developing students. This topic is already understudied in current literature, and future studies must further investigate these findings to determine whether gifted student athletes truly differ from their peers on baseline concussion assessment measures.
References


McCrory, P., Meeuwisse, W. H., Aubry, M., Cantu, B., Dvořák, J., Echemendia, R. J.,
Engebretsen, L., Johnston, K., Kutcher, J., Gusiewicz, K., Herring, S.A., Iverson, G.,
Jordan, B., Kissick, J., McCrea, M., McIntosh, A., Maddocks, D., Makdissi, M., Purcell,
concussion in sport: the 4th International Conference on Concussion in Sport held in


McGrath, N. (2010). Supporting the student-athlete's return to the classroom after a sport-related

shoulders of the giants of psychometric intelligence research. *Intelligence, 37*(1), 1-10.

Meltzer, L. & Krishnan, K. (2007). Executive function difficulties and learning disabilities:
Understandings and misunderstandings. In L. Meltzer (Ed.), *Executive function in

*Clinics in Sports Medicine, 19*(4), 821-834.

administration affects baseline neurocognitive test performance. *American Journal of
Sports Medicine, 39*(11), 2325–2330.

Retrieved from https://www nfhs org/articles/high-school-sports-participation-increases-
for-29th-consecutive-year/


