Effects of Biological Sex and Socially Identifiable Sex Roles on Immediate Post-Concussion Assessment and Cognitive Test (ImPACT) Baseline Measures

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Table of Contents

List of Tables

Introduction

Sports represent a vital function to society, resulting in communal benefits, physical health and wellness, and economic outcomes, moreover across the lifespan (Perks, 2007; Trudeau & Shephard, 2005; Barron et al., 2000). Nearly half of the children in the United States between the ages of 5 and 18 participate in organized sports (Monroe et al., 2011). Correspondingly, along with increased participation in sports among school-aged children, there also is an increasing rate of injuries, particularly in the scope of recreational and contact sports. Specifically, head injury as a result from sports participation represents a main concern; approximately 1.6 to 3 million concussions occur annually (Covassin, Crutcher, & Wallace, 2013). In response, to ensure the safety of the athlete, development of concussion protocol represents an ongoing focus and interest for both diagnosis and management of the athlete. The Immediate Post-Concussion Assessment and Cognitive Test, otherwise known as the ImPACT (Schatz & Maerlender, 2013), represents the most widely used assessment tool for this purpose. The ImPACT offers a preseason baseline assessment, as well as a post-concussion assessment, to properly diagnose a concussion and assist in return-to-play decisions.

With the widespread use of the ImPACT, it is imperative to address perspective assumptions regarding neurocognitive performance variances between sexes. It is necessary to determine if assumptions pertaining to biological sex differences may apply to the ImPACT (i.e., girls have slower reaction times than boys do). In addition, it is crucial to evaluate if expectations pertaining to socially identifiable sex roles may relate to the ImPACT (i.e., more masculine individuals, independent of whether or not the individual is biologically a boy or girl, have quicker reactions times than more feminine individuals).

Specifically, while using the ImPACT, will sex variances (individual differences associated to biological sex: male and female) attribute to cognitive-performance measures? Variances attributed to sex would suggest that interpretation of the ImPACT differs in the context of both cognitive-specific metrics, such as verbal memory and reaction time, and sex differences. Alternatively, a lack of sex differences would indicate that inconsistencies in cognitive-specific metrics across pre- and post-measure would suggests that sex would not represent a potential confound. Correspondingly, will sex role variances (individual differences attributed to socially identifiable sex roles: masculine, feminine, androgynous) attribute to cognitive performance measures? This offers another consideration regarding clarification of pre- and post-measure interpretations. Prior studies have examined sex differences on the ImPACT in the collegiate setting (Covassin et al, 2006; Covassin et al. 2007), and no studies have examined sex differences in a younger sample, specifically high school students. As such, this study will seek to replicate Covassin et al. (2006, 2007), albeit using a younger sample, specifically students ranging from 8^{th} to 12^{th} grade. By using a younger sample, it can be determined whether results from Covassin et al. (2006, 2007) generalize across ages, or perhaps that sex-based and sex role-based differences may have variable patterns, particularly with younger age groups.

Sports Participation

Athletic Performance

Societal Benefits. Perks (2007) reported that sports represent a contribution to the overall betterment of society. More specifically, sports participation positively influences social capital, defined as the features of social organization, such as networks, norms, and social trust, which facilitate coordination and cooperation for mutual benefit. Sports represent associational activities that require unity and teamwork to function. It requires an intentional interaction across participants, spectators, or volunteers. Informal social connections established through participation in a sport club or league may additionally increase the likelihood that individuals engage in other kinds of social activities in the community. As an example, parents of children who participate in sports may plan social events within a parent network and later allow their children to congregate outside the sport atmosphere. One can project that there is a positive relationship between an active sports program and community wellness. Further research has shown that community involvement predicates active community sports participation opportunities (Perks, 2007). For example, community cohesiveness may be greater facilitated through a successful community-supported high school football program, rather than the development of a community-wide recycling program.

Physical Activity. Physical activity offers an important measure in promotion of the overall health and wellness of youth. Trudeau and Shephard (2005) stated: “Physical activity in childhood has been analyzed mainly in the context of favoring immediate health and wellness and as a habit for increasing habitual physical activity levels in adults” (p. 90). Trudeau and Shephard further suggested that physical activity in youth hinders the

development of cardiovascular disease as an adult. Besides the benefits of improved health later in life, sports participation and subsequent physical activity provide an immediate benefit for children, such as increased self-esteem, development of motor skills, and bone health (Trudeau & Shephard, 2005).

Wellness and Education. Through physical education and wellness promotion, children develop respect for their bodies and enhance their self-awareness concerning both health and achievement. Beyond physical benefits, there are also social and cognitive benefits; children will learn how to interact with others and consequently develop their cognitive skills, further contributing towards their academic achievement. Children exposed to sports at an early age have an opportunity for promotion of social skills and emotional experiences that would not be available through other avenues.

When referring to the term *sport*, Bailey (2006) states: "Sport is a collective noun and usually refers to a range of activities, processes, social relationships, and presumed physical, psychological, and sociological outcomes" (p.397). Regular participation in sports accounts for a longer and better quality of life. Evidence shows that those who have developed fundamental movement skills are likely to be active during childhood and later in life (Bailey, 2006). The incorporation of physical education and sports in schools has encouraged many adults of the next generation to live healthy and physically active lives (Bailey, 2006). Regular activity also contributes to the reduction of stress, anxiety, and depression. The contribution of physical activity to cognitive development is evident in studies that suggest a positive relationship between intellectual functioning and regular physical activity for adults and children (Bailey, 2006).

Social Outcomes. Participation in high school athletics has a relationship to education and labor market outcomes. The *National Longitudinal Survey of Youth* revealed that men at the age of 32 who participated in high school athletics had 31% higher wages than those who did not participate (Barron et al., 2000). This may be due to the types of qualities that one builds within team activities attained through sports. Group skills potentially offer a valuable asset to the industrial world; it is plausible that the foundations created by sport participation affect societal outcomes and socialization skills.

Prevalence of Injuries in Sports

Injury Rate. Again, approximately half of American children participated in organized sports between the ages of 5 and 18. Correspondingly, approximately 4.3 million sports and recreational injuries occur annually among school-aged children (Monroe et al., 2011). Regarding the cause of injury, research suggests that football and basketball reflect the most common and frequent sources of sports-related accidents. Monroe, Thrash, Sorrentino, and King (2011) found that the most common type of injuries in sports is closed head injuries, followed by lacerations, and then fractures. Fractures were the most prevalent in football compared to basketball. Over a three-year period, Kerr et al. (2014) showed that 44 athletic trainers reported 6,034 football injuries in the U.S, further representing an alarming rate for a singular sport.

Head Injuries in Sports. Concussions represent the main concern for contact sports and recreation, considering that approximately 1.6 to 3 million head injuries and concussions occur annually (Covassin, Crutcher, & Wallace, 2013). Lincoln et al. (2011) indicated that numerous longitudinal studies have examined the increase of concussions over time. Furthermore, there is a significant trend in the growing rate of concussions, especially in

football and other direct-contact sports (Lincoln et al., 2011). Recent studies support the proposal that over 100,000 concussions occur annually in high school sports (Rosenthal et al., 2014). The report of emergency room visits for concussions has grown 200% from 1997-2007, although this data is not completely attributable to solely high school athletes (Lincoln et al., 2011). Considering the increased reporting of concussions and the frequency of them in high school athletics, the need for concussion management and testing has subsequently gained interest among athletic trainers, school administrators, and others in the scope of common contact sports, as well as sport activities less known for collision and contact (Lincoln et al., 2011).

Historical Foundations for Neurocognitive Testing

History

Simpson (2005) indicated that in the 1790s, Franz Joseph Gall developed a theory of functional localization in the brain. The theory and practice was later termed *phrenology*. Gall proposed that the shape of the skull based the underlying shape of the brain, and therefore certain regions were influencing particular characteristics of humans. Phrenology, later rejected as a valid scientific process and diagnostic tool, paved the way for the fields of neuropsychology and neurocognitive testing.

Boake (2002) reported that there were forms of psychological and perceptual tests before the Binet-Simon Intelligence Scales, such as the Tactual Performance Test developed by the American psychologist, Henry Goddard, as well as a set of "anthropometric" measures, further developed by Francis Galton. James McKeen-Cattell coined the term "mental test" in 1890. His discoveries lead to the production of the digit-span test, which measures a process called prehension; his research is defined as "the mind's power of taking on certain material" (Boake, 2002, p.384). Furthermore, Boake reported that in 1905, Alfred Binet and Theodore Simon published a scale used for measuring intelligence. The scale consisted of 30 brief cognitive tests and took approximately 40 minutes to administer. With the combination of both phrenology and the growth of psychological testing, scientists were able to create neuropsychological tests to assess the functions and capacities of the brain for the benefit of the patient.

Snowman and McCown (2013) indicated that in 1916, Lewis Terman of Stanford University revised Binet's test to translate it from French to English. It proved to be a popular test, now known as the *Stanford-Binet Intelligence Test*; it used a global numerical

value known as the intelligence quotient (IQ). Charles Spearman, a British psychologist, identified two factors that comprise a child's intelligence, including one that affects performance on all intellectual tests and a set of specific factors that affects performance on only specific intellectual tests. Spearman noticed that children who did exceptional on one section of the test were most likely to do well on the other sections. Snowman and McCown (2013) additionally indicated that in 1975, David Wechsler pointed out that intelligence may be better represented as the global capacity of the individual to act purposefully, think rationally, and deal effectively with the environment (Snowman & McCown, 2013). With the development of intelligence testing and the numerical value for intelligence, the future of psychological testing would evolve to incorporate numerical values for varying cognitive abilities.

The Modern Age. Epstein and Klinkenberg (2001) reported that present-day neurocognitive testing involves a revolutionized form of such testing, considering most of the tests are computerized. A variety of research tests the validity, reliability, user acceptance, and cost-effectiveness of these computerized tests (Epstein & Klinkenberg, 2001). There are different types of computerized tests, along with modern adaptations, which display identified questions and then solicits participants' responses. This is most similar to traditional test-taking protocols. Computers can also personalize tests to accompany individuals based on their simultaneous performance. It has been suggested that test-takers using computers provide answers that are more genuine and experience less test anxiety in comparison to others who may take a traditional pencil-paper type test (Epstein & Kilinkenberg, 2001). The *American Psychological Association Ethics Code* specifically addresses computerized testing in sections regarding competence, "Clinicians should practice

within their area of competence. They should be aware of the issues of incorporating technology into clinical practice" (Schulenberg & Yutrzenka, 2004, p.478). Clinicians are also accountable for the applicability of computer-generated reports. One issue pertaining to the policy is the use of the "if-then" paradigm by computerized assessments. Lastly, clinicians must use technology with the goal to increase knowledge regarding test-takers and subsequently use testing protocol to improve and enhance the quality of tests to attain this goal (Schulenberg & Yutrzenka, 2004).

Types of Neurocognitive Assessments for Head Injuries

Computer Applications

Neurocognitive assessments for concussions have historically been deviated from the traditional pencil-and-paper test administered by a neuropsychologist and physician. Computerized testing has become the norm for concussion management in the last two decades. Based upon a review of the literature, it was determined that there are three main batteries, specifically the CogState, CNS Vital Signs, and the ImPACT.

The CogState. Bangirana et al. (2015) reported that the CogState measures include reaction time, working memory, learning, and attention. Computer-based results allow for the avoidance of human error and a reduction in the required time to complete tasks in the test, which is portable and can be administered with an available Internet connection. The test takes approximately 30 minutes to complete and is adaptable to various languages.

CNS Vital Signs. Brooks et al. (2014) indicated that CNS Vital Signs represents another neuropsychological test, which offers rapid administration and has applications with pediatric patients. CNS Vital Signs offers embedded validity indicators that are automatically calculated. The indicators determine if the participant gave a genuine effort on the test, further confirming validity of the results. The test is comprised of seven neuropsychological subtests to assess cognitive capabilities, similar to the CogState and ImPACT.

The ImPACT. This computerized assessment takes approximately 25 minutes to complete. The test contains six neuropsychological tests designed to measure different aspects of cognitive functioning including attention, memory, processing speed, and reaction time. There are four generated composite scores: Verbal Memory, Visual Memory, Visuomotor Speed, and Reaction Time. Descriptions and neurocognitive domains

measured in the ImPACT subtests are shown in Table 1. Numerous studies have examined the validity and reliability of the ImPACT (Ott et al., 2014). A review of the literature most recently suggests that there may be an underreporting of symptoms on the baseline test to avoid losing playing time after a possible concussion is sustained (Meier et al., 2015).

Review of ImPACT Implementation and Psychometric Evaluation

When considering the format of a literature review, Kaplan and Saccuzzo (2009) identified two distinct types. The first is a thematic literature review. The researcher identifies a theme, and then proceeds to cite the literature based on the designated theme. Within this mode, the author discusses the main ideas from the study, but does not actually take many specific details from any of the studies. Contrary to thematic literature review, the next model is the study-by-study review of the literature. This method provides a broad theme with specific details about each study throughout the review. The method chosen for the present review of the literature is the latter, or a study-by-study review. The ImPACT literature has approximately a 10-year history, starting with Schatz et al. (2006).

ImPACT Literature

Schatz et al. (2006). The authors proposed that sustaining one concussion enhances the probability of sustaining another concussion, especially if an athlete does not recover properly from the initial concussion. Schatz et al. (2006) propose that Barth et al. (1989) initiated the movement of identifying concussions based on baseline preseason neurocognitive testing and comparing set values to post-concussion measures. It is important to note that neurocognitive testing has greater accuracy when the symptoms are self-reported in concurrence with further neuropsychological testing. The ImPACT uses both of these features and regularly yields valid and reliable results (Schatz et al., 2006, p. 91-99). This article offered one of the first comprehensive reviews on the topic.

Fazio, Lovell, Pardini, and Collins (2007). Fazio, Lovell, Pardini, and Collins (2007) sought to examine the relationship between post-concussion symptoms and their relationship to initial neurocognitive test performance. When considering this relationship,

concussive symptoms must be initially identified. Further diagnosis is assisted when a specific disturbance is identified in the cognitive ability of the individual after sustaining a traumatic force to the head or the body (i.e., short-term memory). The ImPACT potentially may inhibit a player's ability to continue to play if concussive symptoms are identified through testing. Considering the magnitude of this action, professional expertise, along with careful scrutiny of post-concussive ImPACT results, is required to determine if the athlete may suitably be ready to return to action. Authors reported that neurocognitive test performance and self-reported symptoms by a player may not always be concurrent.

Table 1. ImPACT Subtests

ImPACT Subtests	Descriptors and Neurocognitive Domain Measured
Word Memory Test	Immediate Score vs. Delayed Score out of 12 total words Presented with a list of words, then asked to recall after presented with a distractor Verbal recognition memory (learning and retention)
Design Memory Test	Memorization of shapes Shapes are displayed in sequence, participant asked to recall which shapes were preset after a distractor, shapes change direction in recall Spatial recognition memory (learning and retention
X's and O's Test	Memory of X's and O's vs. interference, first test to account for reaction time Participants must type “Q” when presented with a red circle, “P” when presented with blue square Visual working memory and cognitive speed
Symbol Match Test	Number corresponds to symbol, repeated 27 times, calculating scores based on hidden and visible numbers Symbols correspond with a number 1-9, participants must memorize Memory and visual-motor speed
Color Match	Stroop Effect, Color Blindness Must click when they see appropriate color with name of color Impulse inhibition and visual-motor speed
Three Letters Test	Average letters counted vs. average counted correctly Shown 3 letters, asked to click buttons 25-1 as a distractor, then must recall 3 letters Verbal working memory and cognitive speed

Symptoms in isolation identified 65% of concussed athletes, while 83%, or an additional 18%, were identified via neuropsychological testing two days post-concussion. When self-reported symptoms and neuropsychological testing were combined as a diagnostic tool, there was a 93% identification rate of concussed athletes, offering a 10% improvement when self-reported symptoms and neuropsychological testing were completed as separate and distinct testing mechanisms.

The authors lastly touted concerns regarding traditional neuropsychological testing formats. Traditional neuropsychological testing may be completed via paper and pencil, which can be not only time consuming and costly, but also cannot be administered in a group setting. As such, the use of computerized neurocognitive testing for the assessment of concussions and concussion management may offer a better alternative. The authors suggest that computer-based testing, such as the ImPACT, is not only cost-efficient, but can be administered in a short time span, or approximately 25 minutes. The authors reported the ImPACT to have an 89.4% positive predictive value and an 81.9% negative predictive value. This study specifically examined the differences between various groups to determine any differences in test performance, specifically concussed symptomatic, concussed asymptomatic, and control participants. The overall difference between the groups was significant in their scores in the six categorized tests of the ImPACT. The findings were concurrent with previous research, revealing an imperfect relationship between symptom reporting and neurocognitive performance. This represents an important finding, considering an athlete may be likely to underreport his or her symptoms in hopes to return to play sooner than advised (Fazio et al., 2007).

Kontos, Elbin, Covassin, and Larson (2010). Kontos, Elbin, Covassin, and Larson (2010) sought to explore differences in performance on this test between African American and Caucasian males. Williams (1997), as reported by Kontos et al. (2010), suggested that racial and ethnic variances represent an individual difference to consider in the use and interpretation of neurocognitive testing. Early studies have indicated choice differences in neuropsychological testing results between Caucasian and African Americans. In regards to differences in neurocognitive testing, there has only been a difference in the memory subset between Caucasian and African Americans on the *Test of Memory and Learning* (Kontos et al., 2010). However, using the *Arizona Battery for Communication Disorders of Dementia*, Sandifer and colleagues (2005) found that White male and females scored higher on Total Overall and the Linguistic Expression component, using the *Arizona Battery for Communication Disorders of Dementia*. As such, past research, considering its variability in results, advises that gender and race, as contributing factors towards interpretation of neuropsychological testing, should not be studied single-handedly and should be included with educational factors such as SES, reading level, and educational background.

The study used a sample of 48 Caucasian and 48 African American concussed high school and collegiate student-athletes. Over the course of the two-year study, an athletic trainer or team physician diagnosed concussions. Each concussed athlete was administered the ImPACT at two and seven days post-concussion. The participants did not differentiate on their scores in regards to baseline or post-concussion verbal memory, visual memory, reaction time, and total reported symptoms. There were no differences in baseline testing as well. This finding, along with previous research, suggests that the ImPACT is culturally equivalent and effective in measuring neurocognitive performance, particularly across two

racial-ethnic groups in the present study. The findings indicate that there should not be an equivalent test for other races or ethnicities besides the original ImPACT (Kontos et al., 2010, p. 734-744).

Meehan et al. (2011). Meehan et al. (2011) sought to investigate the prevalence of neurocognitive testing for concussions in the high school setting in the U.S. This study concluded that computerized neurocognitive assessment is the preferred method of evaluation, because it is available, convenient, accurate, and sensitive for assessing athletes that are at a high risk for concussion. In general, the computerized test is relatively simple to obtain and is easier to administer than a full neuropsychological assessment. The usual procedure for the computerized testing is basic; the athlete performs a preseason baseline test and then performs the test again after a concussion is believed to be sustained. The results of the post-concussion test are then compared to the baseline test to determine if there is a large enough decrease in cognitive ability to diagnose the athlete with a concussion. Ferrera et al. (2001) published a survey of athletic trainers that revealed only 1.9% of the respondents use neurocognitive testing when making return-to-play decisions. Later in 2006, Pleacher and Dexter conducted a survey determining that only 16% of primary care respondents had access to neurocognitive testing within the week of a sustained injury. More recently, a survey suggests that approximately 25% of high school sport-related concussions were diagnosed with the use of computerized neurocognitive testing in 2008-2009 (Meehan, d'Hemecourt, & Comstock, 2009).

The *High School Reporting Information Online* (HS RIO) was the source for the gathered information in the present study. Any high school that employs an athletic trainer qualified for the study. The survey had a 97.3% response rate from 178 schools. Of the

responding schools, approximately 40% used computerized neurocognitive testing in concussion management. Of that 39.9%, the majority used the ImPACT (93%). Over two-thirds of the schools that use computerized neurocognitive testing only tested certain sports. 85.9% of schools perform both baseline and post-injury tests. All schools reported using the results from the neurocognitive test as a tool to determine if an athlete can return to play. In an academic year, the percentage of computerized neurocognitive testing rose from 25.7% to 41.2%.

With the growing rate of concussions and the support of the media, it is likely that schools are reaching out to professionals to aid in the decline of concussions and premature return to play. It is difficult to determine an athlete is functioning without a baseline test to compare to the post-concussion results. Considering that the prevalence of computerized neurocognitive testing has risen, it may be suggested that students are likely to understand that a lower baseline test score will be a way of limiting their chances of being diagnosed with a concussion and therefore not missing playing time. It is important to note that the ImPACT should be used with other clinical assessments, such as symptoms reporting and postural control, to increase diagnostic accuracy (Meehan et al., 2011).

Krol et al. (2011). With symptom reporting being so critical to the assessment of concussions, an accurate reading should be used in every test. Symptom reporting can be influenced by many factors, including demographical, clinical, or methodological variables. Literature has stated that the social aspects of reporting symptoms, such as method and type of information, can have an effect on the accuracy of the reporting. Specifically, information collected via interview can be subject to “interviewer effects,” which are based on the characteristics of the interviewer. This is importation to take into consideration when

determining the symptoms of concussions from athletes directly. Iverson et al. via Krol et al. (2011) examined the difference between symptoms reporting to an interviewer versus a questionnaire in mild traumatic brain injury (mTBI). The questionnaire received approximately three times more symptoms than the average of the symptoms acquired in the interview. Krol et al. explored the differences in concussion symptoms obtained via questionnaire and symptoms obtained in an interview, with the gender of the interviewer as the independent variable. Participants in the self-report group reported a greater total symptom score (M=8.71) than participants in the interview group (M=5.43). There was a significant difference between the groups that were interviewed by a male interviewer (M=1.96) as opposed to a female interviewer (M=5.00). Given these findings, it is important to consider the method of intake of symptoms in the overall assessment, and the same measure should be used at baseline and post-concussion (Krol et. al., 2011).

Schatz and Maerlender (2013). According to Schatz and Maerlender (2013), the reliability, validity, and utility of the ImPACT computer-based neuropsychological test, for the purpose of the diagnosis, assessment, and management of sports-related concussions, have been documented and debated in literature. While there may be some skepticism about computer-based neuropsychological assessment for concussions, the ImPACT offers the most widely-used measurement for sports-related concussions. The ImPACT test has been developed over the course of its lifetime since 1999, originating as a file on Windows machines, to the online application through a web browser. The initial test generated three composite scores, including memory, reaction time, and processing/visuomotor speed. Visual memory and impulse control were introduced later, primarily for research purposes and not direct, clinical applications.

The purpose of the Schatz and Maerlender study was to validate the existence of a two-factor structure on the ImPACT (memory and speed) using the currently used composite scores, as well as evaluate the utility of the two-factor with respect to the ImPACT's reliability and validity. The first study collected a baseline sample for the ImPACT of 21,357 middle school, high school, and collegiate athletes, with a mean age of 15.5. A concussion sample was obtained, composed of 560 middle school, high school, and collegiate athletes that completed a preseason baseline test, sustained a concussion, and were treated within seven days. The results of the first study concluded that the variance of factor analysis (Verbal Memory and Visual Memory as "memory," Visuomotor Speed and Reaction Time as "speed") for the baseline group, as well as the concussion group, were almost identical (72.5% to 78.8%). The second study was to analyze the one month, one year, and two year test-retest reliability. Intra-class correlation coefficients (ICCs) were calculated as an indicator of test-retest reliability. The ICC scores for memory and speed were both higher than the composite scores of the three samples that were analyzed. The two-factor composite scores yielded greater reliability than the use of individual composite scores. It also should be noted that concussed athletes share higher levels of post-concussion symptoms, representing decreased variance relative to a wider range of post-concussion scores among memory and speed (Schatz & Maerlender, 2013, p. 791-797).

Resch et al. (2013). Resch et al. (2013) identified the potential test-retest differences of the ImPACT. The study used two time intervals to examine if the ImPACT composite scores would reach an ICC value of 0.75 or higher. The two time intervals were tested in two different groups located in different countries. Approximately half of the composite score values fell below acceptable reliability for clinical interpretation. The ICC values in group 2

were less than group 1, with group 2 experiencing a longer timeframe between the tests. This indication makes it clear that the reliability of the ImPACT decreases over time, therefore warranting more frequent baseline testing (Resch et al., 2013).

McKay et al. (2013). As stated by McKay et al. (2013), neuropsychological baseline testing is resource intensive and is not always possible. This is an important matter to consider since baseline is very important to the diagnosis of a concussion. This particular study examined concussions among elite ice hockey youths. Concussions account for approximately 15%-18% of all injuries sustained within the sport for the young population. It is vital that there is a range of baseline tests that is population-specific, given that resources are limited in most clinical and athletic settings. When considering the baseline testing instrument, the tester needs to take into account that, as adolescents increase in age, they increase in cognitive ability, therefore performing better on neurocognitive tests. Although there are reported differences in scoring between sexes, the present study did not find any sort.

The purpose of the McKay et al. (2013) study was to determine population-specific reference values and psychometric properties of the ImPACT within elite youth ice hockey. It was also intended that information be presented in terms of clinical interpretation of composite and symptom scores. The baseline test was administered to the participants and took approximately 30 minutes to complete, yielding the five composite scores for visual memory, verbal memory, visual motor processing speed, reaction time, and impulse control. The ImPACT also provides a total symptom score, based on the ratings of 22 post-concussion symptoms on a scale of 0 to 6. The baseline test did not yield any differences between sexes and the concussion history. The present study produced the same results as the

youth hockey groups' average collegiate baseline results. All composite scores fell within the average range as well. The only issue that the authors of the present study have encountered was recall bias in that the youth may not have been able to recall all of the concussion symptoms in their past, as well as their medical history (McKay et al., 2013, p. 141-151).

Covassin, Crutcher, and Wallace (2013). Although it is recommended that the sustainment of a concussion be assessed on the sideline immediately, the ImPACT has also been used as a measure beyond immediate assessment. Typically, an athlete experiences several types of symptoms beyond the actual concussion, such as cognitive, behavioral, sleep, and somatic symptoms, for an extended period of time. During the post-concussion period, if an athlete partakes in a physical or cognitive activity, it is likely that his or her symptoms will be worsened. Research is actively being conducted on cognitive recovery.

Covassin, Crutcher, and Wallace (2013) investigated the effects of a 20-minute cognitive task on the symptoms of a concussion 3 and 10 day periods post-concussion. While neurocognitive assessment is the leading method in diagnosing concussions, the present study is particularly significant when considering the administration could prolong the symptoms. The objective was to examine if the concussion symptoms worsened immediately following the participants' performance on the ImPACT. A cross-sectional study design was used to compare the concussion symptoms from baseline, three days post-concussion, and 10 days post-concussion.

A total of 165 high school and collegiate athletes served as the participants. Each participant was officially diagnosed with a concussion by a professional within the field. The athletes experienced a significant decline in their test performance after the 3-day period in each category (verbal memory, visual memory, reaction time, and motor processing speed).

For the test on day 10, visual memory and motor processing speed scores both returned to baseline scores. More importantly, after 3 days post-concussion, the athletes exhibited greater symptoms of headache, nausea, dizziness, sadness, mental fogginess, and visual problems, compared to the ImPACT test after the concussion was sustained. Therefore, the study showed that a neurocognitive test after the concussion does in fact prolong the symptoms. This is an important concept to consider, especially since neurocognitive assessments following concussions are the leading method for diagnosis. However, the study did take into consideration that the athletes were also attending school after the concussion; therefore, the 20-minte test itself may have not prolonged the symptoms of the participants (Covassin, Crutcher, & Wallace, 2013).

Ott, Schatz, Solomon, and Ryan (2014). The ImPACT is a widely-used instrument that must be diversified for different cultures and languages. According to the ImPACT developers, the test requires a sixth-grade reading level to generate an accurate report on the diagnosis of a concussion. The ImPACT is available in 21 different languages. According to the 2010 census, 16.3% of the population in the U.S. is Hispanic. The Census Bureau estimates that by 2050 the population will be 30% Hispanic, resulting in an increase of Hispanic athletes in the population. This prediction only increases the necessity of the ImPACT to be fully accurate and culturally adaptable. Ott, Schatz, Solomon, and Ryan (2014) examined patterns in neurocognitive test performance between bilingual Spanish and English athletes, as well as English-speaking athletes. The results revealed a significant difference between performances on the ImPACT, with the Hispanic-speaking participants testing better in English but not necessarily better than English-speaking participants. This information is important for researchers and clinicians as they administer and interpret the

ImPACT across different languages and cultures, especially with the Hispanic population (Ott et al., 2014).

Meier et al. (2015). With the ImPACT and neurocognitive testing and concussion management increasing in popularity, the possibility of falsifying results were suggested to potentially be a realistic concern. As discussed, symptom reporting is just as important as the neuropsychological testing that accompanies concussion management. Whether athletes report their symptoms could be a determining factor. Meier et al. (2015) sought to examine the environment in which athletes are more likely to report their symptoms appropriately. They compared self-reported symptoms in an onsite athletic facility versus a confidential research setting. Athletes completed the ImPACT at their athletic facilities under supervision of athletic trainers following a diagnosed concussion. Athletes also completed the ImPACT at a research institute in confidentiality. To test for symptom reporting accuracy, the Hamilton Anxiety Rating Scale and Hamilton Depression Rating Scale were also administered. Athletes in the athletic facility reported significantly fewer symptoms than those in the confidential research setting. The study supported the notion that there needs to be a better method of education for athletes and athletic trainers on the severity of concussions. Athletes need to realize that sustaining a concussion and not properly treating it can lead to additional damage and possibly longer time away from their sports. Ignoring the symptoms for purposes related to playing time can be detrimental to the athlete's career and future cognitive functioning. The underreporting of concussion symptoms should be addressed in all settings to ensure the safety of the athletes (Meier et al., 2015).

Identification of Definitional Difference between Sex and Sex Roles

Sex refers to the biological and physiological differences between males and females. Sex roles are identified by the social generalization of behaviors, activities, or attributes that society recognizes as appropriate for men and women, identified as masculinity or femininity (Suar & Gochhayat, 2016). Societal norms produce an understanding of qualities that are more suited or preferable for a male (masculine), as well as for a female (feminine). When these roles overlap one another for an individual, they are considered androgynous.

"Sex-role orientation is measured by preference for masculine or feminine activities" (Mullis and Bornhoeft, 1983, p.17). It is important to note that masculinity and femininity are not opposite ends of a spectrum per se, but rather qualities that an individual can possess equally. The environment actively contributes to a child's path to establishing their gender identity, as well as their sex-appropriate behavior. Gender identity reflects societal norms and expectations, often preparing the path for the child beforehand (Mullis and Bornhoeft, 1983).

Sex and Sex Role Differences in Baseline and Post-Concussive Neuropsychological Measures

Frommer et al. (2011) examined sex differences in concussion symptoms and reporting. It is reported that females respond differently to concussions by being more cognitively impaired after a concussion. There were no differences in symptoms reported; however, there was a differentiation between sexes on which symptoms were reported. Bazariean et al. (2010) found that three months post-mTBI, males had significantly lower odds of lingering mTBI symptoms than females. Dick (2009) examined gender differences in concussion incidence and outcomes. If there is a specific gender possibility for concussion risk, symptoms, and recovery, then there needs to be gender-specific protocol guidelines. While there is limited research pertaining to sex differences in concussion symptoms, it is reported that females are more likely to sustain a concussion participating in contact sports.

In regards to differences between sex roles and neuropsychological performance, limited research has been found that specifically addresses this relationship, due to the amount of additional variables. Mullis and Bornhoeft (1983) suggested that children who exhibited a preference for masculine toys were more likely to perform better on tasks pertaining to spatial abilities, specifically the Peabody Picture Vocabulary test, Presechool Embedded Figures Test, and Piagetian classification task. Similarly, it was suggested that children who show a preference for feminine toys were more likely to perform better on tasks pertaining to verbal ability. However, the study also suggested that sex-role orientation alone may not be the cause of differences in cognition. Meurling, Tonning-Olson, and Levander (2000) examined the relationship between the BSRI and a computerized neuropsychological test (APT, used for neuropsychological diagnoses), but they did not find any significant

correlations with sex roles and the subtests measuring reaction time, finger tapping, k-test, grammatical reasoning, perceptual maze test, or word recognition test.

Antill and Cunningham (1982) sought to explore the function of sex roles in ability tests. Tests pertaining to mechanical reasoning, for example, are preferable for masculine individuals, while tests pertaining to speed and accuracy were preferable to feminine individuals. However, this study noted that masculinity and femininity cannot be referred to one another independently as opposite ends of a spectrum, but rather as continuous qualities that can both exist in an individual, thus termed androgynous. They found that more masculine and androgynous individuals scored higher than feminine and undifferentiated groups in tasks pertaining to mechanical reasoning. Likewise, higher feminine and androgynous individuals scored higher on speed-accuracy tests than masculine and undifferentiated individuals. These results prompt the need for further explanation.

Differences Identified by Cognitive Measures

While there is empirical evidence for differences in cognitive abilities among the sexes, the topic remains controversial. Wilder and Powell (1989) recognized that males consistently outperformed females on tests of mathematical and spatial ability, similar to the visuomotor composite of the ImPACT, and females outperformed males on tests of verbal ability, similar to the ImPACT score of Verbal Memory. This trend is supported through the literature, although there has been a tendency over the years of the gap between males and females closing in physical test performance.

Royer and Wing (2002) found that in high school students, females continue to outperform males in tests pertaining to verbal skills. Contreras et al. (2007) acknowledged that males continue to outperform females in regards to spatial ability tasks. This could be explained by several theories, first being that females are presumed to be slow and meditative, while males are said to be fast and impulsive. Other possibilities suggest that females display poorer time management than males, females present low levels of confidence in their ability to solve spatial tasks, and there is the presumed unwillingness of women to guess (Contreras et al., 2007).

Hedges and Nowell (1995) examined differences in sexes among mental testing. Females performed slightly better on reading comprehension tests, perception speed, and associative memory. Although these differences were present, it was suggested that the average differences were generally small. Regarding the specific categories of the composite scores of the ImPACT, sex differences are discussed further in the next section.

History of Differences between Sexes

ImPACT Composite Score Categories

Visual Memory. Visual memory, or sometimes referred to episodic memory, pertains to the dual processes of both episodic memory and working memory (Pauls, Petermann, and Lepach, 2013). In the scope of the present study, visual memory composite measures pertain to the design memory test scores and X's and O's average test scores. Pauls and colleagues also offered literature support, further documenting women over men in the scope of episodic memory tasks, generally requiring the memorization of faces, words, or letters that had to be retrieved following the task. Herlitz1 and Rehnman (2008) also found that there are slight differences in episodic memory favoring women, especially with word and letter recognition involved. Given these findings, there is a need for further exploration in sex differences of visual memory tasks.

Verbal Memory. For the present study, Verbal Memory will be measured by the composite score with the average of the ImPACT's Word Memory test, Symbol Match test, and Three Letters test. Research has identified sex differences in verbal ability and verbal memory. Bleecker et al. (1988) recognized that women had higher levels of verbal intelligence on the Rey Auditory Verbal Learning Task, thus scoring higher than males on the test which required specific recall of words in a recognition trial. Sex differences in verbal learning have been shown in experimental tasks as well as neuropsychological measures. Although these changes may exist, it is difficult to pinpoint exactly why. Kramer et al. (1997) reported that sex differences in verbal ability are minimal; however, in adolescents, females are superior to men on verbal memory tasks such as verbal selective reminding procedure. This idea was supported by the data of their experiment when females

outperformed males on five learning trials. Hartshorne and Ullman (2006) reported that women are specifically better at verbal memory tasks, such as remembering word lists, reflective of declarative memory. The literature identifies some differences, although they are generally small.

Reaction Time. Males continuously outperform females in tests measuring spatial ability tasks, and likewise women outperform males in regards to verbal skills assessment. With that being said, sex differences in cognition compose a popular topic in psychology. Further, Dykiert, Der, and Deary (2012) stated that men outperform females on tasks pertaining to visuospatial and quantitative ability. Men reportedly have faster reaction times than women across the lifespan throughout the literature. Although reaction time is reported to improve from childhood to adulthood, remain steady, and then decline in late adulthood, males continually show a greater reaction time than females (Dykiert, Der, and Deary, 2012). Reaction time has even been broken down into segments, with Lynn and Ja-Song (1993) finding no differences in decision-making time, but some difference between sexes in the movement to complete the task. Reaction time is a useful measure for cognitive ability, which is why it holds great value on neuropsychological tests, such as the ImPACT.

Visuomotor Speed. Visuomotor speed is recognized through various terms, such as visual-spatial ability or motor processing speed. On the ImPACT, Visuomotor Speed is computed by the speed of X's and O's interference, as well as the correct responses on the Three Letters test. When it comes to visuospatial activities, males are favored over females in performance (Herlitz, Airaksinen, and Nordstrom, 1999). Throughout the literature, there is a suggested trend; males outperform females on visuospatial and cognitive tasks. Prinzel and Freeman (1995) explored differences in visual-spatial ability between males and females, and

they replicated previous studies of males outperforming females on spatial tasks that required mental object rotation. Herlitz, Airaksinen, and Nordstrom (1999) sought to measure differences between sexes on memory tasks that pertained to verbal memory and visuospatial abilities. The results indicated that there were some slight differences in visuospatial tasks based on tasks with mental rotation favoring men. The literature once again addresses verbal ability ranking females over males, while males outperforming females in visuospatial skills.

Sex Differences on ImPACT

Covassin et al. (2006) sought to explore sex differences in baseline performance on the ImPACT. The importance of recognizing differences in baseline performance is for the betterment of the athlete, so that these differences can be taken into consideration for post-injury concussion assessments. Proper baseline assessment is a necessity to provide an accurate depiction of the athlete's concussion history, as well as overall cognitive function when being compared to the norms. The study used the ImPACT version 2.0. Females outperformed males on baseline Verbal Memory scores, while males outperformed females on Visual Memory scores. There was no significant difference in Reaction Time or Visuomotor Speed on the baseline tests.

Covassin et al. (2007) once again explored differences in sex among collegiate athletes, but rather in neuropsychological function and post-concussion symptoms. The ImPACT version 2.0 was again used, showing no significant differences between sexes on baseline scores. However, on post-concussion tests, females performed significantly lower than males on visual memory scores. All other ImPACT composite scores yielded no significant differences. While Covassin and colleagues used a sample of collegiate athletes in both studies, there is a need for determining a possible difference between sexes for a high

school population. While young adults are reported to perform consistently on cognitive tests over their lifespan, the need to establish a baseline protocol for junior high and high school athletes is evident. Although the results of the Covassin studies are inconsistent, the previous literature recognizes cognitive performance differences between sexes in the scope the categories of the ImPACT composite scores. With these differences being prominent, there could be a developmental difference between high school and college samples, thus warranted the present hypotheses. It is noted that there are no identifiable, published studies pertaining to ImPACT performance and sex roles to-date. The present study recognizes the potential relationship between sex roles and neurocognitive performance, thus warranting incorporation into the present methodology.

Hypotheses

Hypothesis 1.

Hypothesis 1A. As previously stated, it is recognized throughout the literature that tasks pertaining to visual memory tend to favor females over males. Therefore, it is hypothesized that females will outperform males in regards to the ImPACT measure of Visual Memory.

Hypothesis 1B. A common trend throughout the literature shows that females continuously outperform males on tasks examining verbal ability. Specifically, Kramer et al. (1997) emphasized that adolescent females were superior to adolescent males on verbal ability tasks. It is hypothesized in the present study that females will outperform males on the ImPACT measure of Verbal Memory.

Hypothesis 1C. It is proposed that reaction time is quicker in males than females as stated in Dykiert, Der, and Deary (2012). Accordingly, it is hypothesized that males' reaction times will be quicker than females' on the ImPACT measure of Reaction Time.

Hypothesis 1D. In regards to visuospatial tasks and processing speed, it is suggested throughout the literature that males outperform females on visuospatial and cognitive tasks (Prinzel and Freeman, 1995). It is hypothesized that males will outperform females on the ImPACT measure of Visuomotor Speed.

Hypothesis 2

In the scope of neuropsychological testing and sex roles, there is limited research due to the overwhelming amount of extraneous variables. However, as mentioned previously, it has been shown by Antill and Cunningham (1982) that tasks of mathematical ability were more preferable to individuals with higher levels of masculinity, while tasks of speed and

accuracy were more preferable to individuals with higher levels of femininity. It is once again important to note that masculinity and femininity are qualities of an individual, with androgyny being classified as the overlapping of the two traits.

Hypothesis 2A. It is hypothesized that individuals with higher levels of masculinity will perform better on the ImPACT measure pertaining to Visuomotor Speed and Reaction Time.

Hypothesis 2B. It is hypothesized that individuals with higher levels of femininity will perform better on the ImPACT measures of Verbal Memory and Visual Memory.

Method

Problem

In the present study, the following research-based questions were addressed:

Question 1. Do sex differences occur on four different measures on the ImPACT?

Question 2. Do sex role differences correlate to four different measures on the ImPACT?

Accordingly, the four measures of the ImPACT scale were examined in relation to sex and sex role differences. The methodology addresses this problem in the administration of a neuropsychological testing instrument, namely the ImPACT, to individuals at a high school level, not only comparing biological sex differences, but also through sex roles, measured and identified from the Bem Sex Role Inventory.

Participants. Fifty-seven participants were obtained from E.D. White Catholic High School, a small private high school (approximately 750 students) located in Thibodaux, LA. Institutional Review Board feedback was sought, considering that the participants were not of the age of consent, or younger than 18 years of age. Because participants were less than the age of consent, permission was obtained from parents, and likewise assent was obtained from the participants. Prior to completion of the study, Institutional Review Board approval was obtained. A copy of both the permission and assent forms are included in the Appendix. Related to participant demographics, specific participant profiles are offered on Tables 2-4. Normed baseline ImPACT scores are identified in Table 5.

Materials. In order to obtain neuropsychological functioning and sex role identification, psychological testing was administered. The ImPACT takes approximately 25 minutes to complete and includes a demographic section, symptom inventory, and six

subtests measuring attention, memory, processing speed, and reaction time. The demographic section requests information concerning the participant's age, gender, medical and educational history, and information pertaining to sport. Numerous studies regarding the ImPACT's validity and reliability have been conducted, as previously reported in the prior literature.

While it has been discussed throughout the present study, it is important to differentiate sex from sex roles. Sex refers to a biological basis for distinguishing between male and female, while sex role refers to societal expectations of gender. In order to account for sex roles, the BSRI was used. The BSRI short form consisted of three columns related to their respected measures of masculinity, femininity, and androgyny. There were 20 items per columns with words or characteristics that were more preferable to the category in which they were in. Holt and Ellis (1998) identified coefficient alphas computed for masculinity and femininity revealed high reliability (Masculinity alpha = .86; Femininity alpha = .82). The BSRI test-retest reliability within a sample of 28 males and 28 females was confirmed to be highly reliable over a four-week period (Masculinity r = .90; Femininity r = .90; Androgyny r = .93). Further, this study sought to validate the BSRI in an adult population, and they did so by confirming that the items on the inventory accurately depicted the criteria that were preferable to masculine and feminine individuals. Choi, Fuqua, and Newman (2009) displayed similar results to the previous literature of the BSRI's reliability, having consistent scores with previous studies using the BSRI.

Procedure. In order to evaluate sex differences, participants were asked specific questions relating to whether they were male or female. Based upon this distinction, sex differences on ImPACT measures were obtained. The students were then administered the

ImPACT during their designated hour for a Physical Education class. Similarly, in order to measure sex role differences, the BSRI was used, or administered to the students. More specially, the BSRI was administered after the ImPACT in order to potentially prevent any expectancy effects on behalf of the participants.

Table 2. Participant Demographics

	Male	Female
Number of	22	35
Age (years)	M=15.1 (SD=2.0)	M=14.4 (SD=1.1)
Height (inches)	M=68.9 (SD=4.1)	M=64.1 (SD=2.6)
Weight(lbs.)	M=157.1 (SD=38.4)	M=123.5 (SD=23.8)
Years of Education	M=9.0 (SD=2.0)	M= 7.5 (SD=2.2)

Table 3. Participant Sport Participation

Sport	Total	Sport	Total
Football	10	Softball	1
Baseball	2	Volleyball	3
Cross-Country	2	Swimming	4
Track	1	Dance	6
Soccer	4	Cheer	2
Basketball	3	Fishing	1
No Sport Part.	11	Other	7

Table 4. Participant Concussion History

Concussion History	Male	Female
Number of Concussions	7	2
Concussions Resulting in Loss of Memory	3	0
Confusion as Result of Concussion	3	0
Games Missed Because of Concussion	27	0

Table 5. Baseline Percentile Scores of ImPACT Participants

Superior	92-99%
High Average	76-91%
Average	25-75%
Borderline Impaired	2-8%
Impaired	<1-2%
Student GPA vs. Percentiles	
A-B Student, High SAT	65-75% or higher
B-C Student, Average SAT	35-45%
D-F Student, Low SAT, Learning Disability	20% or lower

Results

Exploratory Analysis of Constructs.

A pairwise correlation was used to examine potential relationships between demographic and concussion symptom variables with ImPACT measures. Results are as shown in Table 6. There was a significant relationship between Age and Visuomotor Speed $r(53) = .34$, $p = .02$ as well as Age and Reaction time $r(53) = -.33$, $p = .01$.

In addition to the pairwise correlation analyses, additional analyses were performed to identify potential interactions of Sex X Sex Roles on the four measures of the ImPACT. A 2 (Male, Female) x 3 (Masculine, Feminine, Androgynous) ANOVA was used for each analysis. There were no significant interactions, with all *p*s $> .05$.

Table 6. Demographic and Concussion Symptom Variables and ImPACT Measures

	Years of Ed.	Age	Height	Weight	Total Symptoms	Visuomotor Speed	Visual Memory	Verbal Memory	Reaction Time	Number of Concussions
Years of Ed.	-									
Age	.63*	-								
Height	.56*	.64**	-							
Weight	.40**	.59**	.75**	-						
Total Symptoms	-0.1	-0.1	-0.1	-0.13	-					
Visumotor Speed	-0.17	.31*	0.16	0.15	0.03	-				
Visual Memory	-0.05	-0.12	0.07	-0.11	-0.17	.341*	-			
Verbal Memory	-0.18	0.08	-0.09	-0.13	0.06	.43**	.37**	-		
Reaction Time	-0.19	-0.33*	-0.22	-0.17	-0.11	-0.43**	-0.21	-0.18	-	
# of Concussions	.39**	.44**	.362**	.36**	-0.09	0.143	-0.02	0.15	-0.04	-

**Correlation is significant at the 0.01 level (2 tailed)
* Correlation is significant at the 0.05 level (2 tailed)

Sex Differences

Reaction Time. Reaction Time in males (M=.64, SD = .09) was faster than females (M = .66, SD = .14), albeit the difference was not statistically significant, $t(53) = -.90$, p = .37.

Visuomotor Speed. Males scored higher in the Visuomotor Speed component (M = 35.43, SD = 6.33) than females (M = 33.56, SD = 7.67); nonetheless, the difference was not significant statistically $t(53) = .98$, $p = .33$.

Visual Memory. While Visual Memory in females (M = 75.0, SD = 12.9) was greater than males (M = 70.9, SD = 13.75), the difference was not statistically different, $t(53) = -1.12$, $p = .27$.

Verbal Memory. Verbal Memory was higher in males (M=84.1, SD = 9.8) than females (M = 79.6, SD = 13.1), although the difference was not statistically significant, $t(53) = 1.44$, $p = .16$.

Sex Role Differences

It was hypothesized that differences in measures on the ImPACT would be equated to sex role variations, specifically across different levels of femininity, masculinity, or androgyny.

Femininity. Femininity is defined as the "possession of a social role behaviors that are presumed to be characteristic of a girl or woman" (Vandenbos, 2015). The items on this portion of the BSRI are to be said as more "desirable" for female participants (Heerbroth & Ramanaiah, 1985). Femininity scores were not statistically correlated with Reaction Time, $r(52) = -.22$, $p = .11$; Verbal Memory, $r(52) = .10$, $p = .46$; Visual Memory $r(52) = .24$, $p = .08$; Visuomotor Speed, $r(52) = .18$, $p = .19$; and Cognitive Efficiency Index, $r(52) = .034$, $p = .81$.

Masculinity. Masculinity is defined as "the possession of social role behaviors that are presumed to be characteristic of a boy or man" (VandenBos, 2015). The items on this portion of the inventory are to be said as more "desirable" for male participants (Heerbroth &

Ramanaiah, 1985). Scores on masculinity questions were not statistically correlated with Reaction Time, $r(52) = -.005$, $p = .97$; Verbal Memory, $r(52) = -.14$, $p = .30$; Visual Memory, $r(52) = .11$, $p = .41$; and Visuomotor Speed, $r(52) = .04$, $p = .77$.

Androgyny. Androgyny is defined as the "presence of male and female characteristics in one individual; the state of being neither masculine nor feminine in appearance" (VandenBos, 2015). Androgyny levels were not statistically correlated with Reaction Time, $r(52) = .07$, $p = .63$; Verbal Memory, $r(52) = -.16$, $p = .24$; Visual Memory, $r(52) = .16$, $p = .25$; and Visuomotor Speed, $r(52) = .003$, $p = .98$.

Discussion

Sex Differences

The present study sought to investigate whether biological sex contributed to differences in ImPACT scores, alongside sex roles. Previous research on the ImPACT has taken a generalized approach to examining differences, as stated in the review of the ImPACT literature. Covassin et al. (2006) recognized that females outperformed males on baseline verbal memory scores, while males outperformed females on visual memory scores among collegiate athletes. However, these results could not be replicated with Covassin et al., 2007. Although it is generally accepted that cognitive variances continue throughout the lifespan across the sexes, the present results suggest sex differences do not occur or exists on the ImPACT within the present methodology or design. The present study did not find any statistically significant differences among the means of ImPACT scores between males and females, particularly with a high school sample. Again, these results are concurrent with Covassin et al. (2007). Moreover, statistically significant correlations could not be found between sex roles and performance on four measures of the ImPACT.

Our results contradict previous studies which concluded otherwise, examining sex differences across physical test performance as well as spatial ability, which will be discussed in the below narrative. However, using the analogy of comparing apples and oranges, present results may be considered in the context of type of cognitive tasks performed on the ImPACT in comparison to comparable tasks performed in other studies. Other studies evaluated sex differences using different tests not used within the ImPACT resulting in the lack of ability to compare apples with apples, but instead demand the reality that direct comparisons may not be applicable across non-ImPACT-based studies.

Cognitive Performance Differences

Visual Memory. While there has been literature to support differences in visual memory attributed to sex, the present study failed to produce evidence of this trend. Pauls and colleagues (2013) supported the notion that women continually outperform men on memory tasks that reflect verbal skills, while men continually outperform women on visual-spatial tasks. The present study did not find any such evidence. In regards to head injury and visual memory, loss of memory is a primary symptom. Reid and Kelley (1993, p. 245) stated that "accurate identification of memory deficits becomes essential in providing effective rehabilitation." It is vital to the recovery of the athlete that all deficits are properly identified, thus the purpose of the visual memory component of the ImPACT. When a coach or a trainer assess an athlete for a possible concussion, they must consider any type of memory loss, without any relation to the athlete's sex.

Verbal Memory. When administering the ImPACT, it may be assumed that differences in performance are inherent between boys and girls. More specifically, girls are better at verbal skills tasks and boys are better at physical tasks. Moreover, boys should perform better on reaction time and visuomotor speed, and girls should perform better on verbal memory and visual memory. Similarly, results should be considered in the context of these prejudices. (From an observational standpoint, as the ImPACT was administered in the present study, males were continuously rushing to get through the test, while females took their time in each task to ensure their accuracy in their answers, thus potentially affecting their speed-accuracy skills.)

The results of the present study failed to support the previous literature regarding sex differences in verbal memory. This is contradictive to Kramer et al. (1997), which identified

females as being superior to males in tasks pertaining to verbal memory and verbal skills. Wright, Schmitter-Edgecombe, and Woo (2010) acknowledged that one of the most profound cognitive deficits produced by a head injury is episodic and verbal memory impairment. Thus, verbal memory represents an important cognitive function affected by head injury. It may be suggested that in almost every team sport, verbal memory is equally important as communication skills. If this cognitive ability is impaired, it could lead to miscommunication and possible injury for the athlete, alongside being a component to return-to-play decisions. Coaches, trainers, and professionals should not form conclusions from performance on verbal memory measures based on sex, but rather individual baseline performance in comparison with post-injury test.

Reaction Time. The results of the present study demonstrated that sex differences did not occur in reaction time on the ImPACT. These results are inconsistent with Dykiert, Der, and Deary (2012), who stated that men reportedly have faster reaction times than women across the lifespan throughout the literature. The present study also fails to support the study by Lynn and Ja-Song (1993), who found no differences in decision-making time, but some difference between sexes in the movement to complete the task. Stuss et al. (1989) stated that reaction time tests have consistently revealed slowness of information processing, which reflects a deficit in divided attention after head injury. Zahn and Mirsky (1999) suggested that a prominent and consistent feature of closed head injury is inhibited motor activity as displayed in slower reaction time. As such, a disadvantaged reaction time could potentially harm an athlete during sport participation or potentially another athlete in the activity. The ImPACT recognizes the importance of reaction time; thus, it is a featured component to the diagnosis and management of concussions. Again, the ImPACT should not be interpreted

based on comparisons between sexes in reaction time, but rather on their own individual performance in comparison with post-injury ImPACT tests.

Visuomotor Speed. The results of the present study contradict previous findings of males outperforming females significantly on visuospatial tasks. These findings are not concurrent with the findings of Prinzel and Freeman (1995), who found that males outperformed females in tests that involved rotation of an object in visuospatial tasks. The findings of the present study are incongruent to Herlitz, Airaksinen, and Nordstrom (1999), who found that men slightly favored women in the tasks of visuospatial ability. In the scope of sport activities, it is important for a coach, trainer, or physician to recognize that impairment of an athlete's motor-processing ability could lead to injury or worsening of a head injury. Athletes will oftentimes not realize their immediate symptoms and therefore continue to play. Kelty-Stephen, Qureshi Ahmad, and Stirling (2015) identified a method of diagnosing concussions with a tracing task designed to specifically measure visuomotor deficits, thus outlining the importance of visuomotor capabilities of an athlete in the diagnosis and management of concussions.

Sex Role Differences

While sex may be defined as the biological and genetic traits that distinguish between males and females, sex roles are defined as behavior and attitudinal patterns characteristically associated with being male or female as defined in a given society (VandenBos, 2015). Sex roles were again recognized as masculine, feminine, and androgynous measures using the BSRI (Hoffman and Borders, 2001). In the present study, a relationship was not found amongst sex roles and the four measures of the ImPACT.

In the scope of neurocognitive test performance and sex roles, it was shown that there may only be differences in test performance if there is a presence of stereotype activation among the participants (Tempel & Neumann, 2016). In previous studies on sex roles and cognitive performance, it was shown that masculine gender role women performed better than female gender role women on measures of spatial ability (Tempel & Neumann, 2016). In contrast, our study showed no relationship. In theory, a coach may assume that in a more stereotypical masculine sport, the player is more likely to perform better due to a strong competitive nature, while more feminine individuals may want to achieve higher results to feel accepted by their peers and not face scrutiny. Considering these results, this again suggests that assumptions based on non-cognitive data are not reliable measures of performance when establishing a concussion protocol. Rather, baseline and post-test measures must be considered. It may be suggested that as individuals view themselves as more masculine, they may be more aggressive and competitive, and similarly more likely to perform better than individuals who are more feminine. The present study is concurrent with previous literature examining sex role difference and performance, presenting that sex role differences, if any, are minor and not significant enough to acknowledge (Eriksson and Lindholm, 2007).

Examination of Potential Confounding Variables

The present study used a high school sample to examine potential differences in performance of ImPACT measures among males and females, as well as a potential relationship between sex roles and ImPACT measures. A potential confounding variable that differentiates the present study from Covassin et al. (2006/2007) is the inclusion of age as a secondary feature, although not manipulated theoretically nor experimentally. Luna et al.

(2004) stated that mental abilities continue to develop during adolescence, as these improvements are supported by the development of specific cognitive capabilities such as processing speed, voluntary response suppression, and working memory.

There was a significant correlation between age and Reaction Time as well as age and Visuomotor Speed. This potentially can be attributed to the level of development in students' cognitive abilities with an increase in age representing faster reaction time and visuomotor processing speed. Brychta et al. (2013) claimed that girls' reaction time abilities peak at age 15, while boys continue to improve in reaction time abilities into adolescence. They also identified a discrepancy in performance with tasks that required movement, with adults outperforming pre-adolescent children. In regards to the age effects in the Visuomotor Speed measure, Gur et al. (2012) found changes for both accuracy and speed over from ages of 8-21. The most noticeable improvement was in executive control functions, specifically attention and motor speed. The present study produced results similar to the literature pertaining to maturation and its effects on reaction time and visuomotor (or motor-processing) speed.

These results could potentially be addressed in another study examining age and its effects on ImPACT measures. For example, the examination of age effects can be seen by a comparison of two distinct age group performance to one another on ImPACT measures, such as young adults versus pre-adolescents, or "junior high" versus "senior high." The present study's sample size may have limited the statistical power of finding other potential confounding variables. Perhaps, future directions should focus on using a larger sample size with a broader range of demographics.

Generalized Discussion

In contrast to the ongoing literature supporting differences in physical and cognitive performances between the sexes in non-ImPACT measures as addressed previously, the present study did not find such evidence. More specifically, there was no significant findings between sexes nor sex roles and the ImPACT measures using a high school sample. Additionally, in agreement to prior studies examining the ImPACT and the interrelationship of interpretation with sex, the present study did concur with those studies (e.g., Covassin, 2007). It may be inferred through the present study that the ImPACT has best use when comparing baseline test results with post-concussion test results, as opposed to supposition based on biases pertaining to sex or sex roles among high school students. Coaches, trainers, and administrators should not make assumptions of baseline or post-concussion test results based on sex, such as male or female. Likewise, athletic personnel should not make decisions solely based on an individual's feminine or masculine characteristics. Rather, players' baseline and comparative post-head injury test results should dictate game-play decisions or the need for further neurocognitive testing.

The present study recognizes a need to establish a concussion protocol for all athletes. The findings of the present study were concurrent with that of Covassin et al. (2007), which exclusively, previously examined a collegiate sample, wherein, the present study used strictly a high school sample. Moreover, the present study also examined sex roles and neurocognitive performance, particularly with a high school sample. Results suggests neither sex, nor sex roles affect performance on the ImPACT. Based upon present sample, it may be generalized that lack of difference on this test, primarily attributable to sex and sex role

differences, transfers to both a collegiate (i.e., Covassin et al., 2007) and high school sample (i.e., present study).

Many potential weaknesses are present with the current study. First, the present study used a high school sample, with limited diversity regarding socioeconomics and geographic range. The participants were enrolled at a private high school in a rural community of south Louisiana, thus limiting the generalizability of the current findings. Second, a limited sample size was used, based on convenience sampling. Random assignment across geographical and socioeconomic domains may have further increased generalizability and interpretation of results. Third, the present study was completed in September and October, or during the "middle" of a football season. It would be potentially beneficial for the test to be administered in the preseason to make sure there are limited, lingering cognitive discrepancies from a potential head injury that takes place once the season starts. Also, it would be recommended that time samples at multiple times during the academic year should be obtained to offer a broader time-based perspective. In summary, future studies should seek to increase the statistical power with a larger sample size in both private and public school samples to incorporate more demographics, socioeconomic statuses, and comparative academic achievement. Further, it is also recommended that the study should be completed across many months to obtain a broader sample of athletes across various times during the applicable seasons.

Conclusion

With an increasing rate of participation in sports throughout high school, college, and then the professional level, there is a much greater prevalence of injuries. Specifically, sport-related concussions are becoming more prominent across the lifespan. More importantly, the need to establish a universal concussion protocol is evident. The accurate diagnosis and management of concussions starts with a proper baseline assessment followed by a post-concussion assessment. As noted throughout the present study, the most widely used system for these assessments is the ImPACT, albeit examination of this instrument in the context of sex and sex role variable is sparse. This study contributed regarding examination of differences between sexes and sex roles and their relationship with ImPACT baseline measures, specifically Verbal Memory, Visual Memory, Reaction Time, and Visuomotor Speed. Again, Covassin et al. (2007) exclusively examined a collegiate sample finding no statistical significant difference between males and females, and the results of the present study were concurrent with these findings; again, statistical differences were not found across the sexes or by identified sex roles on four measures on the ImPACT.

As such, it is suggested that a coach or trainer, when administering the ImPACT, should make any assumptions based solely on baseline performance in regards to sex, sport, or masculine and feminine characteristics, alongside a post-concussion assessment once the head injury is believed to have occurred, or a return-to-play decision needs to be made. The easy access and administration of the ImPACT makes it an efficient tool for any matter regarding a concussion. Moreover, these decisions should be based on baseline and post-concussion measures, not based on supposition predicated on sex or sex roles.

Lastly, future directions should continue to focus on baseline performance in the scope of sex differences. The present study did not find differences in across measures of cognitive functioning. These results may be attributable to other factors, such as lack of statistical power, limited sample size, or lack of diversity of sample (i.e., sample taken from primarily an upper-class, Caucasian high school in rural South Louisiana). It would be recommended that future studies not only include a large sample size, but also include a broader sample diversity, including individuals across both wide-ranging socioeconomics and also racial parameters. Although statistical significant was not found (i.e. differences in baseline measures were not found across four measures on the present test), the present study has heuristic value. That is, future studies should not only examine sex and sex role variations in the ImPACT, but also other tests, which may be used for equally important endeavors, such as intelligence and academic aptitude testing.

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Appendices

Appendix 1. Consent

Parental Permission Form
Dear Parent,

We are requesting that you permit your child to participate in a research study to establish a baseline for ImPACT concussion management test and related psychological variables. This thesis study is for Grant Chiasson, a graduate student majoring in psychology, being supervised by Dr. T. Scott Smith from the University of Louisiana-Lafayette. Your child's health and physical education class was selected to participate in the study. We will also ask your child to assent to join in the research study and sign a form for his or her participation.
On Monday, October 17, we will administer a set of computer-based and paper-pen tests during your child's physical education class. The tests will contain your child's name on it so that all the parts of the tests can be kept together. Once the tests are complete and the data is entered, all documentation of your child's name will be discarded. The sole purpose of using your child's name is for organization of the material to be completed. Your child will be asked to complete the ImPACT neurocognitive concussion management test, a personality inventory, a self-esteem inventory, and a gender-role identity inventory. These tests will be taken on the desktop computers in the school's media center.
The benefit of this study is in helping the researchers make the concussion management protocol safer and more accurate for high school athletes. The tests will be given out during a class period and will take less than one hour to complete.
The researchers expect to publish the results of the surveys in a professional journal, but at no time will the name of your child or of any child participating in the study be made public. Only the results of all the participants as a group will be published. The tests will be locked in a filing cabinet in the researchers' office until the results have been entered into the computer and then the surveys destroyed by shredding.
Your child's participation in this research is strictly voluntary and he or she may refuse to participate or to discontinue his or her participation at any time during the study without bias or any problems from the school, from the university or from the researchers.
If you have any questions about this research or wish to speak with the researchers, please do not hesitate to call Dr. Smith at 337-482-6591 or Grant Chiasson at 985-438-2569. If we are not at the telephone, please leave a message on the voice mail and one of us will contact you as soon as possible.
PERMISSION:
I understand that my child's physical education class has been selected to participate in a research study. I understand my child will participate in a series of psychological and neurocognitive tests in this study. I also understand that my child is participating voluntarily and may refuse to participate and/or may withdraw at any time during the study. I agree to allow the researchers to invite my child to participate in the study.
Parent's Name _____ Date: _____

Parent's Signature _____

Child Assent to Participate

Dear Student,

You are being invited to participate in a norming research study linking psychological factors with a baseline concussion management neurocognitive test. You were selected because you attend a high school in the state of Louisiana that was selected for the study. Your physical education class was chosen at random from the list of classes in this school between eighth and twelfth grade, and your parents have agreed you may be part of the study if you would like to do so.

You are not required to be part of this study even though your parents have consented. You may say no at the start or at any time after you have begun, even if you have finished the forms. We ask you to consider filling out the forms because it will help establish a norm for the ImPACT test that will aid in concussion management for high school athletes. If you choose not to be part of the study nothing will happen to you at your school or at the University of Louisiana at Lafayette. Additionally, no one will say anything to you for not being in the study.

The findings of this study will contribute to a safer and more efficient concussion protocol for high school athletes. There is little risk, having to complete the ImPACT neurocognitive test, a self-esteem inventory, a personality assessment, and a gender-role identity inventory. The findings from the study will be written up for a journal by the researchers but your name will never appear in the reports. Your name on the tests are to keep them together. After all the information from the tests are in the computer the forms will be shredded.

If you or your parents wish more information about the research you may call Dr. T. Scott Smith at 337-482-6591 or Mr. Grant Chiasson at 985-438-2569 at the University of Louisiana at Lafayette.

Child's ASSENT to Participate:

I agree to be a part of the research study.

Printed Name: _____

Signature: Date: _____

Chiasson, Grant D. Bachelor of Science, Northwestern State University, Fall 2014; Master of Science, University of Louisiana at Lafayette, Spring 2017
Major: Psychology
Title of Thesis: Effects of Biological Sex and Socially Identifiable Sex Roles on Immediate Post-Concussion Assessment and Cognitive Test (ImPACT) Baseline Measures
Thesis Director: Dr. T. Scott Smith
Pages in Thesis: 71; Words in Abstract: 219

ABSTRACT

This study examines sex differences on the baseline Immediate Post-Concussion Assessment and Cognitive Test (ImPACT), as well as the relationship between ImPACT measures and sex roles in a high school sample. Previous literature has shown that males tend to outperform females in the scope of reaction time and visuospatial performance. Likewise, females tend to outperform males on cognitive tasks, such as those pertaining to verbal and visual memory. There is limited research regarding sex roles and neurocognitive testing, while the present study examined this relationship. Participants were obtained from E.D. White Catholic High School in Thibodaux, LA. The 57 participants were administered the Bem Sex Role Inventory, as well as the ImPACT baseline neurocognitive assessment. A comparison of the means was analyzed using a t-test, while a Pearson Correlation was used to examine the relationship between sex roles and ImPACT measures. There were no statistically significant results. Coaches, trainers, and test administrators should not make assumptions based on sex or sex roles. The ImPACT system is a tool that has been used for the purpose of diagnosis and management of concussions, and will continue to be the most widely used assessment. Future directions should continue to focus on neurocognitive baseline testing for concussions for athletes at the high school level, being that there is limited research in this area.

Biographical Sketch

Grant Chiasson was born and raised in Thibodaux, Louisiana. He attended Northwestern State University where he earned a Bachelor of Science in psychology in 2014. He also attended the University of Louisiana at Lafayette, where he earned a Master of Science in psychology in 2017. His research focused on neurocognitive testing with concussion management and diagnosis, as well as the effects of cell phone distraction. Grant served as a teaching assistant for the Department of Psychology for two years. He hopes to continue his professional career in the field of criminal investigations.