DO CONCUSSION HISTORY AND GENDER INFLUENCE NEUROCOGNITIVE TESTING PERFORMANCE

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DEDICATION

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DO CONCUSSION HISTORY AND GENDER INFLUENCE NEUROCOGNITIVE TESTING PERFORMANCE

by

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THESIS

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Abstract

BACKGROUND: To date, the literature regarding sport concussion (SC) has concentrated primarily on male athletes. Generally, as research on female athletics has increased, there is an overall agreement that female athletes show more impairment post-injury than males. However, more data are needed to determine how SC impacts the female athlete and if that impact is influenced by factors such as age or history of prior concussion.

SUBJECTS: Subjects with and without a previous history of concussion at the high school and college level were included and carefully matched for age, gender, height, and weight. After careful matching, five high school athletes with a history of prior SC were compared with five high school athletes without a concussion history, and 14 college athletes with a history of prior SC were compared with 14 matched college athletes without a concussion history.

METHOD: Data for this study were acquired from a larger study conducted at the University of Texas at Arlington that examined sport concussion in high school and college athletes. Variables included previous concussion history and baseline scores from the ImPACT test. It was hypothesized that female athletes with a previous SC would show more impairment on baseline neurocognitive measures and would report greater symptom severity at baseline testing compared to athletes without a prior SC. In addition, it was hypothesized that female athletes with a previous SC at the high school level would show more impairment on baseline neurocognitive measures than college athletes with prior SC and that high school players would show greater symptom severity compared to college athletes at baseline.

RESULTS: No significant differences were seen on any ImPACT baseline composite scores between athletes with and without a reported history of prior concussion. Similarly, no differences on ImPACT baseline total symptom scores were seen between athletes with concussion versus without a history of prior concussion. Finally, there were no differences on ImPACT composite or total symptom scores between college and high school athletes.

Keywords: ImPACT, sport-related concussion, gender, concussion history

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LIST OF ABBREVIATIONS

SC – Sport concussion

TBI—Traumatic brain injury

mTBI—Mild traumatic brain injury

LOC—Loss of consciousness

ImPACT – Immediate Post-Concussion Assessment and Cognitive Test

CHAPTER ONE

Introduction

Mild traumatic brain injury (mTBI) in athletics, referred to as *sport concussion* (SC), is one potential consequence of participation in sport. SCs were once viewed as minor setbacks and were to be “shaken off” quickly so injured athletes could return to play. That said, SCs have emerged as a major health concern over the last few decades. With increasing media attention, SC now has moved to the forefront of head injury research. As athletic participation has increased, reaching an all-time high at both the high school and collegiate levels (NCAA, 2016; NFHS, 2015), research has struggled to catch up to the impact SC may have on players at the acute and long-term stages.

While much research has focused on male athletes and high profile sports such as football, less is known about SC effects in female athletes. As more and more women participate in sports activities and as the SC incidence rate continues to rise, it has become increasingly important to understand the effects of SC in female athletes, particularly in terms of how age at injury and if cumulative effects of repeated injury may impact symptoms and outcomes. Few studies have investigated the influence of one or more SCs on high school and collegiate females athletes. Our cross-sectional study may provide insight into how adolescent and adult female athletes are affected by SC.

CHAPTER TWO

Review of the Literature

Sport-Related Concussion

Head injuries are generally classified by severity into mild, moderate, and severe traumatic brain injury (TBI). Classifications of TBI can be ascertained several ways using variables such as presence of loss of consciousness (LOC), duration of LOC, post-traumatic amnesia, findings on neuroimaging, or the Glasgow Coma Scale (Teasdale and Jennett, 1974). Mild TBI (mTBI) occurs most frequently, with US totals estimated to range from 1.6 to 3.8 million annually depending on the source of data (Giza and Kutcher, 2014). The number of mTBI's sustained each year is estimated to be 1.7 million and that number is expected to increase annually (US Department of Health and Human Services, 2010).

Defining concussion. The term *concussion*, now defined as a subset of mTBI, did not appear until the Congress of Neurosurgeons published the first official definition in 1966. Until this time, researchers debated a specific set of criteria to correctly identify and diagnose concussion. The term concussion has often been used interchangeably with mTBI and represents a "shaking" of the brain that results from low or high velocity impact which jars the brain inside the skull (McCrory et al., 2013).

The definition of concussion has evolved over the past two decades. Although several definitions for concussion exist, definitions agree on the causal aspects of injury (McCrory, et al., 2009). The 2001 International Conference on Concussion Panel defined concussion as a "complex pathophysiological process affecting the brain induced by biomechanical forces," with several common features of all concussion that encompass clinical, pathological, and biomechanical aspects (Aubry, et al., 2002, p.7.)

The Concussion in Sport Group went on to define several elements of concussion that included direct or impulsive force. A direct injury might result from a blow to the head in helmet-to-helmet tackling, head-to-ground impact, or from a blunt object like a hockey stick or baseball (Mihalik, 2012). Impulse injuries occur when the head is set into motion or stopped without direct contact, and these injuries can result from being stopped suddenly or from stopping something else suddenly, like coming into contact with an opponent (Mihalik, 2012). This thesis will use the Concussion in Sport Group definition described above.

Incidence. The reported incidence of mTBI and SC varies by source. The number of new SCs that go unreported may not be reflected in the annual rates published (McCrea, Hammeke, Olsen, Leo, and Guskiewicz, 2004). Of the projected numbers of mTBI, an estimated 300,000 involve sports and recreation (Zuckerman, Soloman, Forbes, Haase, Sills, and Lovell, 2012).

Collins, Comstock, Dick, Fields, & Gessel (2007) compiled data from nine high school sports (football, male and female soccer, male and female basketball, wrestling, baseball, volleyball and softball) from 100 U.S. high schools during the 2005-2006 academic year. Their survey reported that out of 4,431 total sport injuries, 396 (8.9%) were diagnosed as concussion. The CDC, in the 2011 Morbidity and Mortality Weekly Report, examined the epidemiology of concussion in those under the age of 19 who sustained an mTBI during sporting play by analyzing data collected in a National Injury Surveillance System—All Injury Program (Centers for Disease Control & Prevention, 2011). Data showed that between 2001-09, 6.5% of the ER visits by those younger than 19 were treated for mTBI. This represented a 57% increase during the time span from 153,375 mTBI- related visits in 2001 to 248,418 in 2009 (Centers for Disease Control & Prevention, 2011). Since 2005, Lincoln, Caswell, Almquist, Dunn, Norris, and Hinton (2011) reported a substantial increase (16.5%) in SCs in schools with one full-time and one part-time certified athletic trainer, noting the increase in reporting when trained staff was on hand to diagnose and report instances of SC.

Until the last decade, the incidence of SC has mainly been studied by looking at SC rates among football players. As such, few statistics were available for female sports such as basketball and soccer, and limited data were reported on the incidence of injuries for female athletes overall (Schulz, Marshall, Mueller, Yang, Weaver, Kalsbeek, and Bowling, 2004). In an effort to update incidence information and include data representing female athletics, Marar, McIlvain, Fields, and Comstock (2012) found an overall SC rate of 13.2% with a higher rate of SC among females compared to males. Lincoln and Marar's findings, combined with the CDC numbers, showed evidence of increases in SC among sports other than football.

Mechanism of injury. All TBIs involve a transfer of energy that accelerates or decelerates the head (Mihalik, 2012). Mechanism of injury refers to the physical and physiological changes that result in damage. Animal TBI models were first used to show that moderate and severe brain injury can occur without a direct impact and be attributed to acceleration and deceleration forces (Barth, Freeman, Broshek, and Varney, 2001). Regardless of the trauma source, there is an internal response at the physical and physiological level. The brain is suspended in a viscous substance within the skull known as cerebrospinal fluid (CSF). CSF aids the cranial vault in protecting its contents from jarring against the skull during normal head movements (Vianno, King, Melvin, and Weber, 1989). However, when the head or body is hit with traumatic force, CSF is limited in its ability to keep the brain from moving (Vianno et al., 1989). The resulting motion produces neuronal stretching and metabolic dysfunction (Barth, et al., 2001; Kirkwood and Yeates, 2012).

During the motion of TBI, described above, axons, which make up the white matter of the brain, can be stretched. This process, referred to as axonal shear- strain, occurs when brain tissue is stretched and the axons separate or tear (Vianno et al., 1989). These tears are often termed diffuse axonal injury or DAI. DAI can trigger chemical changes within brain cells that disrupt the cells' natural internal environment, leading to decreased blood flow to the injured area and resulting in changes in brain function. Decreased blood flow, depleted energy reserves at the cellular level, and individual factors such as age and gender can manifest in neurological and cognitive changes before brain cells can repair themselves and return to their normal state (DeLellis, Kane, and Katz, 2008; Vianno et al., 1989).

It is thought that most damage after injury results from trauma that occurs where the brain's grey and white matter meet, making injury difficult to detect (DeLellis et al., 2008). This damage is not uniform across tissue, can be microscopic, and cannot be seen with commonplace neuroimaging technology in clinical settings (Barth, et al., 2001; Vianno and Lovsund, 2010). However, more advanced imaging technologies like diffusion tensor imaging (DTI) may someday help researchers and clinicians better identify mTBI-related pathology.

Assessing Concussion

A variety of clinical measures exist which help clinicians to identify SCs. Testing consists of symptom checklists, brief sideline assessments, computerized and traditional paper and pencil neuropsychological examinations, and balance testing (Belanger and Vanderploeg, 2005). On-field markers of SC such as assessment of LOC, anterograde amnesia, retrograde amnesia, and confusion, are important features utilized by coaches and trainers to recognize potential SC (Collins et al., 2007; Lovell and Soloman, 2013). Since concussion symptoms vary, a combined use of clinical observation, symptom assessment, balance testing, and neuropsychological assessment is often recommended (Resch, Driscoll, McCaffrey, Brown, Ferrara, and Macciocchi, 2013). In a 2013 survey of the National Athletic Trainers Association, an increased use of computerized testing measures was reported (from 15% in 2004 to 44% in 2013), which suggests that the computerized testing approach is rising and expected to increase in the future (Lynall, Lander, Mihalik, and Stank, 2013).

Recent years have seen the advantages in establishing an athlete's pre-season or baseline neurocognitive functioning and balance (Schmidt, Register-Mihalik, Mihalik, Kerr, and Guskiewicz, 2012). Baseline scores give clinicians an idea of an athlete's pre-injury neurocognitive function and postural control, in addition to any symptoms they endorse (Schmidt et al., 2012). Values derived from the baseline assessment allow clinicians to control for an athlete's own abilities or pre-existing conditions that may influence test performance (Covassin, Elbin, Crutcher, and Burkhart, 2012) and help clinicians assess minor neurocognitive changes in an athlete following SC (Barth, Freeman, and Broshek, 2002). Baseline scores can be compared to post SC baseline values to provide clinicians an idea of athletes' concussion-related deficits (Schmidt et al., 2012).

Outcome Following Concussion

As SC has become a high-profile issue, the need to determine how concussion impacts players on and off the field and the variables that may have the most impact on an athlete's injury and recovery trajectory has moved to the forefront of head injury research, with SC emerging as a special topic with unique consequences. The clinical deficits observed as a result of SC can vary significantly across individuals (Barth, et al., 2001). Many things can influence concussion outcomes: potential genetic susceptibility to brain injury, physical strength, and whether the oncoming impact can be anticipated (Mihalik, 2012). Other factors thought to contribute to SC outcomes include age, gender/sex, and history of previous head injury.

Concussion Symptoms. No matter the mechanism of injury, and despite clinical variability, some SC symptoms share similar characteristics and time course. The more common physical symptoms of SC include headache, nausea, dizziness, and double and/or blurry vision (Kirkwood and Yeates, 2012). Longer lasting physical symptoms post-SC are commonly reported to be headache, balance issues, and sensitivity to light and noise (Covassin, Schatz, and Swanik, 2007). Continuing headache, balance problems, and sensitivity to light may be physical symptoms of concussion that linger hours, or days, post-injury; however the duration of symptomology is not a consistent finding across the research.

Neurocognitive functions like concentration, information processing speed, and memory can be impaired following SC. Other neurocognitive symptoms of SC may include inability to recall the event, confusion, or a general feeling of sluggishness (Abrahams, Mc Fie, and Patricios, 2013; Covassin, Elbin, Harris, Parker, & Kontos, 2012; Lovell and Solomon, 2013; Macciocchi, Barth, Alves, Rimel, and Jane 1996). Persistent neurocognitive symptoms of injury may include impaired concentration and other cognition issues such as attention/confusion, memory problems, and impaired information processing speed (Ellemberg, Leclerc, Couture, and Daigle, 2007).

Macciocchi et al., (1996) examined a sample of 2300 college football players who were administered neurocognitive assessments pre-season and following injury to identify deficits following SC. Using these data, a subset of players at the NCAA Division A level who were diagnosed with an SC were compared to a matched sample (by age and education) of non-injured players. Testing following SC showed that injured participants displayed impaired neurocognitive functioning in areas of attention and information processing speed (Macciocchi et al., 1996). In a 2013 meta-analysis representing 3,801 concussed athletes, Dougan, Horswill, and

Geffen (2013) reported varied neurocognitive impairments following SC across studies. Post-injury deficits within this analysis included impaired neurocognitive function and balance.

In addition to physical and neurocognitive impairments post-SC, a range of emotional SC symptoms can result. General feelings of depression and behavioral changes such as increased irritability and sadness can all appear post-injury (Abrahams et al., 2013; Covassin et al., 2012; Lovell & Solomon, 2013; Macciocchi et al., 1996). Researchers examining depression and neurocognitive scores post-injury noted higher levels of depression post-SC when compared to baseline scores in a study with 75 high school and college athletes (Kontos, Covassin, Elbin, and Parker, 2012).

Symptom resolution. Generally the symptoms of SC manifest immediately or within several hours or days after injury. According to several studies (Abrahams et al., 2013; Dougan et al., 2013), symptoms typically resolve within 10 days after injury, although most find full recovery within 5 or 7 days post-injury (Belanager and Vanderploeg, 2005; Macciocchi et al., 1996). A number of investigations have identified a small subgroup of patients who report symptoms lasting past the 10-day window, however, highlighting variability in recovery time (Covassin et al., 2012). In general, as noted in the studies above, younger athletes, females, and those with a history of prior concussions may be particularly susceptible to longer recovery times, suggesting a need for further study of the effect of prior concussion.

Effects of Prior Concussion

A history of prior SC has been shown to impact symptom severity and neurocognitive functioning in athletes post concussion. Physical symptoms, such as headache, may be more pronounced in those with a history of prior SC and these symptoms may last longer in those athletes with a previous concussion history (Covassin et al., 2013). Regarding neurocognitive symptoms of SC, athletes with a history of concussion may exhibit slower reaction times on post-injury testing along with deficits that last longer in the areas of memory, attention, and concentration than do athletes who do not have a prior history of concussion (Covassin et al., 2013; Iverson, Gaetz, Lovell, and Collins, 2004; Wall, Williams, Hatton, Kelly, Murray, Murray, Owen, and Turner, 2006). Athletes with a history of concussion also have a higher risk of sustaining another concussion and may show cumulative neurocognitive impairments over time (Covassin et al., 2013).

While some researchers report that athletes with a history of three or more SC show increased complaints in the areas of cognition, fatigue and migraines (Kontos et al., 2012), other research has found no difference in symptom reporting (Iverson, Brooks, Lovell, and Collins, 2006). However, Iverson's 2006 findings contradict earlier research conducted in 2004 where he found a prior history of SC was associated with more reported symptoms by athletes. While less is known about potential gender differences, some research suggests that a history of previous SC is associated with a higher number of reported symptoms at baseline assessments in both male and female athletes (Mannix, Iverson, Maxwell, Atkins, Zafonte, and Berkner, 2014) and that male athletes with a history of concussion exhibit more symptoms than those who have no history of prior SC or those who have experienced a single episode of SC (Covassin et al., 2013).

Athletes with no previous concussion history have been have been shown to perform better on measures of neurocognitive performance overall than those with a history of one or more SC (Parks, Moore, Wu, Broglio, Covassin, Hillman, and Pontifex, 2015) and those with a history of two or more SC (Covassin et al., 2010). In addition, a prior history of SC may lead to more cumulative neurocognitive deficits (Covassin et al., 2010) and more severity of injury as well as an increased risk of future concussion and a potential second SC within the same season

(Guskiewicz, Weaver, Padua, and Garrett, 2000). A history of prior SC may make athletes more vulnerable to impairments overall (Wall et al., 2006) and lend itself to difficulties in many life areas in the future (Guskiewicz, Marshall, Bailes, McCrea, Harding, Matthews, Register-Mihalik, and Cantu, 2007).

Generally there is an agreement within the literature that male and female athletes who have a history of prior SC may show subtle differences on measures memory and cognitive functioning that exceeds those athletes who have not experienced a prior injury (Belanger and Vanderploeg, 2005). A history of previous SC has been shown to make an athlete 7.7 times more likely to have impaired memory function (Colvin, Mullen, Lovell, West, Collins, and Groh 2009; Iverson et al., 2004), more executive functioning impairments (Ellemberg, 2007; Covassin et al., 2010; Wall et al., 2006) and lowered inhibitions than athletes who have no prior history of SC (Wall et al., 2006), and cumulative impairments may be evident in those with a prior SC than those without (Iverson et al., 2004).

Effects of Gender Following SC

Symptom differences by gender. Certain personal characteristics such as gender and age have been shown to impact symptom severity and recovery following SC (Covassin et al., 2012). Efforts have been made to determine gender differences in presentation, severity and symptom endorsement post-SC. Overall, females have been shown to take longer to become symptom free than males (Berz, Foss, Heyl, Ford, and Meyer, 2013) and experience symptoms that are more severe (Berz et al., 2013; Colvin, 2009). Females have also endorsed more total symptoms post-injury (Broshek, Kaushik, Freeman, Erlanger, Webbe, and Barth, 2005; Benedict et al, 2015; Colvin et al., 2009; Covassin et al., 2012). Females tend to endorse headaches of a more intense nature than males (Colvin et al., 2009) and have higher levels of drowsiness and noise sensitivity post-concussion (Collins, Comstock, Dick, Fields, and Gessel, 2007). Females have also been shown to complain of more sleep disturbance than males and endorse more affective symptoms after injury (Kontos et al., 2012; Zuckerman, Apple, Odom, Lee, Solomon, and Sills, 2014).

Cognitive deficits and gender differences. When it comes to cognitive function assessment, it has been noted that females tend to do better overall on measures of verbal memory and processing speed than males during baseline testing (Covassin et al., 2010; Mannix et al., 2014) and much of the SC literature shows gender differences across various neurocognitive domains post-SC. More specifically, female athletes in a meta-analysis by Dougan et al (2013) were observed to have more neurocognitive deficits than males post SC. Processing speed deficits are often shown post-SC, with female athletes showing greater levels of impairment on complex and simple reaction time measures compared to males (Broshek et al., 2005). Female athletes have been shown to have lower visual memory composite scores than males at both the high school and collegiate levels post concussion (Colvin, 2009; Covassin et al., 2007).

Interaction of Gender and Prior SC

When it comes to gender differences among those who have a history of prior SC, females with at least one prior SC have been reported to show more overall impairment than males (Ellemberg, 2007). Although Brooks et al. (2013) noted no gender differences in neurocognitive scores between male and female athletes with a history of previous concussion, Covassin et al., (2010) observed that males who had sustained three or more SC performed worse on measures of verbal and visual memory than females with the same SC history.

Generally, the literature is consistent in showing impairment following sport concussion in terms of memory and processing speeds, and there is some suggestion that females tend to show greater impairment in these areas than males post-injury. When addressing a history of prior concussion, there is a consensus that most athletes with a history of prior concussion tend to show more cognitive impairment overall than athletes with no previous concussion. The literature is limited in terms of understanding gender differences when looking at the impact of concussion history on neurocognitive function during baseline assessment of athletes with and without a prior history of concussion.

Age and gender differences in SC

Age is a variable that may influence gender differences in SC. Similar to Broshek et al. (2005), Preiss-Fargzanegan, Chapman, Wong, Wu, and Bazarian (2009), when looking at the relationship of gender, age, and symptomology following SC, proposed that gender is an SC risk in adult females). Their findings showed differences by age, with women over the age of 18 experiencing more headaches, dizziness, fatigue, irritability and concentration issues compared to women under 18. This contradicts Colvin et al. (2009), which found that younger women had more frequent and severe post-concussion symptoms.

Kontos et al., (2012) noted that high school participants, regardless of age, reported more baseline symptoms than the college-aged participants in his sample. High school subjects also reported more headaches, but college-aged participants complained of more sleep issues that could be due to other variables outside of SC (e.g., demanding schedule, etc.). That same year, Covassin and colleagues (2012) attempted to ascertain not only how gender may influence SC symptoms but also how age impacted SC symptom reporting, cognition and postural stability. Covassin et al. (2012) found that high school athletes performed worse than college athletes on neurocognitive testing, and that impairment may last 10 to 21 days for high school athletes versus 5 to 7 days for college athletes, supporting the variability in recovery that has been widely noted.

To determine age differences post-SC and to see if those differences affected symptoms and an athlete's return to baseline, Lee, Odom, Zuckerman, Solomon, and Sills (2013) examined symptom presence, severity, and total number, proposing that athletes under the age of 16 would report more symptoms, have greater symptom severity, and take longer to return to baseline when compared to the older athletes. Lee et al. (2013) showed that younger athletes took 1.3 days (on average) longer to return to their own baseline when compared to older athletes, and when accounting for the athlete's own variability, no significant differences were shown post-SC by age. Berz et al. (2013) wanted to determine if there were any symptom severity differences by age or gender after SC. Their data suggested that females younger than 15 not only took longer to become symptom- free than females over age 15 after SC, but that these same females had a greater number of symptoms that took longer to resolve than male athletes in the same cohort.

Summary and Research Aims

SC is often associated with deficits on measures of processing speed, attention span, and memory (Abrahams et al., 2013; Dougan et al., 2013; Ellemberg et al., 2007; Kirkwood and Yeates, 2012; Macciocchi et al., 1996), in addition to various physical and emotional symptoms. Investigation of these sequelae has heightened an interest in factors that affect the presentation of SC symptoms and eventual recovery. Three of these factors are gender, age, and a history of prior concussion. Studies regarding gender and its influence on SC have been limited, with evidence that females take longer to return to baseline functioning after SC (Berz et al., 2013; Colvin et al., 2009; Covassin et al., 2009; Zuckerman et al., 2014), show more deficits than males in reaction time and processing speed (Broshek et al., 2005; Colvin et al., 2009; Ellemberg et al., 2007), and perform worse than males on measures of memory (Colvin et al., 2009;

Covassin et al., 2012). Female athletes also tend to report more severe symptoms post-SC and present with greater symptom severity than male athletes (Berz et al., 2013; Broshek et al., 2005; Colvin et al., 2009; Covassin et al., 2012).

With regard to the potential role of age on post-SC functioning, outcomes are mixed, but studies have shown that younger athletes tend to exhibit more symptoms post-SC such as headaches, dizziness, and confusion (Berz et al., 2013; Kontos et al., 2012), perform worse on post-injury testing compared to older athletes (Covassin et al., 2012), and take longer to return to baseline levels of function post-SC (Berz et al., 2013; Lee et al., 2013). Few studies have addressed gender and age together, but they have shown more post-injury headaches, fatigue and concentration issues for females over the age of 18 (Preiss-Fargazen et al., 2009).

A history of prior SC has been associated with slower processing speed, slower reaction time, impaired attention and concentration, and memory deficits (Colvin et al., 2009; Covassin et al., 2013; Iverson et al., 2004), in addition to a longer time to return to baseline functioning, and other impairments that last longer than athletes with no history of prior SC (Covassin et al., 2013). Other studies show no difference in return to baseline levels of functioning but do show that athletes with a history of concussion report more symptoms post-injury (Brooks et al., 2014; Iverson et al., 2004).

No studies identified in the literature appear to investigate how gender, age, and a history of concussion may interact and how that interaction may impact post- recovery function in female athletes. It has been shown that females generally perform better than males on measures of memory and processing speed and that these areas show higher levels of impairment post SC in female athletes (Covassin et al., 2010; Mannix et al., 2014). Since females have been shown to report more symptoms at baseline and tend to rate their symptoms as more severe (Berz et al., 2013; Colvin et al., 2009; Mannix et al., 2014), it stands to reason that there would be increased symptomology at baseline for female athletes with a history of concussion. This study will examine female athletes at the high school and college level to see if a history of previous SC impacts neurocognitive functioning on measures of memory and processing speed and the number of symptoms reported at baseline in an effort to add to the SC literature as it applies to the female athlete.

Hypotheses

Hypothesis 1a: High school females with a history of one or more concussions will earn lower processing speed, visual and verbal memory composite scores and have slower reaction times on ImPACT at baseline testing than high school females with no concussion history.

Hypothesis 1b: High school females with a history of one or more concussions will report a higher total symptom score on ImPACT at baseline testing than high school females with no reported history of concussion.

Hypothesis 2a: College-aged females with a history of one or more concussions will earn lower processing speed, visual and verbal memory composite scores and have slower reaction times on ImPACT baseline testing than college-aged females with no concussion history.

Hypothesis 2b: College-aged females with a history of one or more concussion will report a higher total symptom score at baseline testing than college-aged females with no reported history of concussion.

Hypothesis 3a: High school females with a history of one or more concussion will earn lower processing speed, visual and verbal memory composite scores and exhibit slower reaction times on ImPACT baseline testing than college-aged females with a history of one or more concussions.

Hypothesis 3b: College-aged females with a history of one or more concussions will report a lower total symptom score at baseline testing than high school females with a history of one or more concussions.

CHAPTER THREE

Method

Participants

Data for this study were part of a larger study conducted at the University of Texas at Arlington that looked at SC in high school and college athletes. Participants were recruited from a private high school and a large public metropolitan university. Sports represented in the data included football, cheerleading, male and female basketball, baseball, softball, male soccer, and track and field. Athletes with invalid ImPACT profiles at baseline were excluded, as were athletes who did not give consent for their data to be used for the study. Data from testing were stored on an encrypted computer or within locked filing cabinets in the office of the principal investigator.

Five female high school athletes with a history of prior SC (mean age = 16.48, SD = 1.02, age range = 14 to 17 years) were identified for this study. A control group of five female high school athletes without a concussion history (mean age = 16.54, SD = 1.01, age range = 14 to 17 years) were matched for age, height, and weight to test hypotheses 1a and 1b. Athletes in this sample were all Caucasian and English speakers. They were primarily right-handed, with only one athlete (with prior concussion) reported as left-handed. Athletes in this sample were involved in a variety of sports across the high school participation level (basketball, volleyball, track and field). Only one athlete reported a history of more than one previous SC.

Fourteen female college athletes with a history of prior SC (mean age = 19.42, SD = .89, age range = 18 to 21 years) were identified for this study. A control group of fourteen female college athletes without a concussion history (mean age = 19.37, SD = 1.09, age range = 18 to 21 years) were matched for age, height, and weight to test hypotheses 2a and 2b. Athletes in this sample were Caucasian ($n = 20$), African-American ($n = 6$), Asian American ($n = 1$), and

Hispanic (*n* = 1). All athletes in this sample were English speakers. They were primarily right-handed, with only one athlete (with prior concussion) reported as ambidextrous. These athletes were involved in a variety of sports across the college participation level (basketball, volleyball, and softball). Only one athlete reported a history of more than one previous SC.

The same five female high school athletes with a history of prior SC were utilized for hypotheses 3a and 3b of this study. A group of five female college athletes with a history of prior SC were matched for height and weight to test hypotheses 3a and 3b (mean age = 19.78, SD = .95, age range = 18 to 21 years). Athletes in this sample were all English speakers and primarily right-handed, with one left-handed high school athlete and one ambidextrous college athlete. Athletes in this sample were Caucasian (*n* = 8), African-American (*n* = 1), and Hispanic (*n* = 1). The athletes were involved in a variety of sports across the high school and college participation level (basketball, volleyball, softball, and track and field), with only two athletes, one at the high school and one at the college level, reporting a history of more than one previous SC.

Procedures

Pre-injury (baseline) ImPACT assessments were conducted as part of each institution's concussion management policy. Data used in the current study were only included after obtaining parental consent and subject assent. In addition to ImPACT outcome scores, demographic information, self-report symptom assessment, and postural stability assessment data were also collected for all participants but postural stability data were not analyzed for the current study.

Participant selection for the separate hypotheses was as follows: from a sample of 118 female athletes identified as high school students in the larger study, 56 participants below the high school level were excluded, leaving five high school participants with previous SC and 57 participants with no previous SC. Five participants for the control group were selected from these 57 and were matched to the five participants with previous SC by height, weight, and age (within 10%) for hypotheses 1a and 1b.

From a sample of 88 female college athletes in the larger study, five participants with no baseline testing scores were excluded. Five subjects with missing demographic information (age, height, weight) also were excluded, leaving 14 college participants with previous SC and 64 with no previous SC. Fourteen participants for the control group were selected from these 64 and were matched to the 14 participants with previous SC by height, weight, and age (within 10%) for hypotheses 2a and 2b.

For hypotheses 3a and 3b, five of the 14 college participants with previous SC were matched to the five high school participants with previous SC by height and weight (within 10%).

Instruments

ImPACT is a 25-minute computerized battery of neurocognitive tests. ImPACT has become a primary tool to help identify cognitive deficits post-SRC, to follow symptom resolution over time, and to help to determine when an athlete should return to play. ImPACT is used by 90% of athletic trainers surveyed (Lynall et al., 2013). Developed in 1998, ImPACT measures self-reported SC symptoms as well as areas of memory, attention and reaction time (Lovell, 2013).

ImPACT, which consists of domains typically affected by SC (Lovell, 2013), was administered at baseline to athletes in the study for a measure of pre-season functioning. ImPACT consists of eight separate subtests, which yield four composite scores including verbal and visual memory, visual motor speed, and reaction time. ImPACT also incorporates an automated validity indicator to assist in the identification of suboptimal baseline assessments. The ImPACT Post Concussion Symptom Scale (PCSS) is completed to help determine what symptoms the athlete is experiencing and their severity (Lovell, 2013).

Reliability. In an attempt to determine the long-term test-retest reliability of ImPACT, researchers looked at 95 college athletes tested at a 2-year interval (Schatz, 2009). Reliability coefficients ranged from .65 for visual memory to .74 for processing speed, when the same test was used, suggesting stability of baseline measures during the 2-year study (Schatz, 2009). In an earlier study by Broglio, Ferrara, Macciocchi, Baumgartner, and Elliot (2007), researchers looked at three testing time points to determine test-retest reliability: baseline, 45 days post-baseline, and 50 days post-baseline. Broglio et al. found reliability coefficients that ranged from .15 to .39 in the time period from baseline to 45 days post-baseline and coefficients from .39 to .61 between day 45 and day 50, suggesting low to moderate reliability on ImPACT testing.

In an additional study looking at test-retest reliability of ImPACT, researchers examined two groups who had never been exposed to the ImPACT battery (Resch, Driscoll, McCaffrey, Brown, Ferrara, & Macciocchi, 2013). Group 1 (n = 46) was given the assessment at three time points: baseline, 7 days post-baseline, and again 14 days post-baseline. Group 2 (n = 45) was tested 45 days after initial baseline testing and again at day 50. Researchers found reliability that varied, with coefficients ranging from .26 to .88 in Group 1 and .37 to .76 in Group 2. It was noted that this variability could lead to misdiagnosis of healthy subjects after baseline testing, suggesting that the reliability of ImPACT may fade over time (Resch et al., 2013). Data also indicated that visual-motor and reaction time composites showed greater reliability than verbal and visual memory composite scores (Resch et al., 2013).

Elbin, Schatz, and Covassin (2011) looked at the online version of ImPACT to determine if its reliability was the same as the earlier desktop version of ImPACT. They tested 369 high school athletes (aged 13 to 18 years) from various sports. Administering two baseline assessments over a one-year period of time, researchers found that the reliability of the online version of ImPACT was greater than that of the desktop version over this period, with coefficients ranging from .62 for verbal memory to .85 for visual motor speed. Visual motor speed composites in these data showed the most stability over time (.85), followed by reaction time (.76), visual memory (.70) and verbal memory (.62).

Validity. Construct and concurrent validity involve the ability of a test to measure what it is designed to assess (Maerlender, Flashgun, Kessler, Kumbhani. Greenwald, Tosteson, and McAllister, 2010). With regard to ImPACT, researchers attempted to determine if the neurocognitive domains being assessed are similar to the domains assessed by other relevant neurocognitive measures (Maerlender, et al., 2010). These researchers compared scores of 54 male, college-aged athletes attained on ImPACT to those from a comprehensive neuropsychological assessment used to detect deficits following TBI. Results showed the construct validity of ImPACT for processing speed and working memory (Maerlender et al., 2010).

An additional attempt to establish the construct validity of ImPACT was conducted by Allen and Gfeller (2010). They compared ImPACT to the standard neuropsychological measures used by the NFL to detect brain injury in a group of college students. Results suggested that both measures assess similar constructs, with overlap in some areas, supporting construct validity of ImPACT testing. It has been noted that ImPACT has the lowest percentage of questionable validity in baseline testing results compared to other computerized testing measures available (Nelson et al., 2015).

CHAPTER FOUR

Results

Preliminary Analysis

For hypotheses 1a and 1b, the sample (n = 10) consisted of five female athletes at the high school level with a history of concussion prior to baseline testing and a control group of five female athletes at the high school level without a concussion history. No significant differences were observed between groups for age, $t(8) = -.10$, height, $t(8) = 1.45$, or weight, $t(8) = .093$, $p > .05$. Table 1 shows the descriptive statistics (means and standard deviations) for the two groups.

For hypotheses 2a and 2b, the sample (n = 28) consisted of 14 female college athletes with a history of concussion prior to baseline testing and a control group of 14 female college athletes without a concussion history. Independent t-tests revealed no significant differences between groups for age, $t(26) = .13$; height, $t(26) = 1.07$; or weight, $t(26) = -.406$, $p > .05$. Table 1 shows the descriptive statistics (means and standard deviations) for the two groups.

For hypotheses 3a and 3b, the sample (n = 10) consisted of five female high school athletes with a history of concussion prior to baseline testing and five female college athletes with a concussion history. No significant differences were observed for height, $t(8) = .11$ or weight, $t(8) = .58$, $p > .05$ for the two groups. A significant difference was reported for age, $t(8) = -5.29$, $p = .001$, as expected. Table 2 shows the descriptive statistics (means and standard deviations) for the two groups.

Descriptive Statistics

For the high school sample (n = 10), Table 3 presents the means, standard deviations, and percentiles for ImPACT scores for the athletes with and without concussion. As shown in Table 3, the mean reaction time composite score of athletes with a history of concussion was within the average range. Mean scores on the visual and verbal memory composites were within the average range, as was the impulse control composite score. The total symptom score of athletes with a prior concussion at baseline testing was within the average range. As shown in Table 3, the reaction time composite score of athletes without a history of concussion was within the average range, as were scores on the visual and verbal memory components and impulse control composite. The total symptom score for these athletes was within the average range.

For the college sample *(n* = 28), Table 4 presents the means, standard deviations, and percentiles for ImPACT scores for the athletes with and without concussion. As shown in Table 4, the mean reaction time composite score of athletes with a history of concussion was within the average range. Mean scores on the visual and verbal memory composites were within the average range, as was the impulse control composite score. The total symptom score for athletes with a prior concussion at baseline testing was within the average range. As shown in Table 4, the reaction time composite score of athletes without a history of concussion was within the average range, as were scores on the visual and verbal memory components and impulse control composite. The total symptom score for these athletes was within the average range.

Table 5 presents the means and standard deviations for ImPACT scores for the selected high school and college athletes who had previous concussions *(n* = 10). The mean reaction time composite score of high school athletes with a history of concussion was within the average range. Mean scores on the visual and verbal memory composites were within the average range, as was the impulse control composite score. The total symptom score of high school athletes with a prior concussion at baseline testing was within the average range. As shown in Table 5, the reaction time composite score of college athletes with a history of concussion was within the average range, as were scores on the visual and verbal memory components and impulse control composite. The total symptom score of the college athletes, shown in Table 5, was within the average range.

In addition to looking at cognitive measures within this sample of concussed high school and college athletes, total games missed by the athlete following SC were examined. On average, high school athletes missed more games (M = 1.8) than college athletes (M = 0). Additionally, high school athletes had a higher number of reported concussions compared to college athletes in the sample.

Results of Hypothesis-Testing

Statistical analyses were conducted using Statistical Package for the Social Sciences version 21. Three family-wise sets of independent t-tests were run for all identified variables with statistical significance set at $p < 0.05$. The confidence interval for all testing interpretation was set to 95%.

Hypothesis 1a. High school females with a history of one or more concussions will earn lower processing speed, visual and verbal memory composite scores and have slower reaction times on ImPACT at baseline testing than high school females with no concussion history.

Independent t-tests were conducted using previous concussion as the Independent Variable (IV) and ImPACT scores as the Dependent Variable (DV) to determine if the two groups differed on measures of visual motor speed, visual memory, verbal memory, and reaction time. Levene's tests for equality of variance were not significant for these variables. No significant differences between concussed female high school athletes and non-concussed female athletes were found for visual motor speed, $t(8) = -.17$, visual memory, $t(8) = -.39$, verbal memory, $t(8) = .38$, or reaction time, $t(8) = .64$, $p > .05$.

Hypothesis 1b. High school females with a history of one or more concussions will report a higher total symptom score on ImPACT at baseline testing than high school females with no reported history of concussion.

An independent t-test was conducted using previous concussion as the Independent Variable (IV) and ImPACT symptom score as the Dependent Variable (DV) to determine if the two groups differed on symptom severity at baseline testing. Levene's test for equality of variance was significant for this variable, so equal variances were not assumed. When the analysis were conducted with unequal variances considered, no significant difference between concussed high school athletes and non-concussed high school athletes was observed for total symptom score, $t(4.9) = 1.11$, $p > .05$.

Hypothesis 2a. College-aged females with a history of one or more concussions will earn lower processing speed, visual and verbal memory composite scores and have slower reaction times on ImPACT baseline testing than college-aged females with no concussion history.

Independent t-tests were conducted using previous concussion as the Independent Variable (IV) and ImPACT scores as the Dependent Variable (DV) to determine if the two groups differed on measures of visual motor speed, visual memory, verbal memory, and reaction time. Levene's tests for equality of variance were not significant for visual motor speed, verbal memory, or reaction time. No significant differences between concussed female college athletes and non-concussed female athletes were found for visual motor speed, $t(26) = .26$, verbal memory, $t(26) = .52$, or reaction time, $t(26) = -.29$, $p > .05$. Levene's test for equality of variance was significant for visual memory, so equal variances were not assumed for this variable. When the analysis were conducted with unequal variances considered, no significant difference between concussed high school athletes and non-concussed high school athletes was observed for visual memory, $t(26) = 1.78$, $p > .05$.

Hypothesis 2b. College-aged females with a history of one or more concussions will report a higher total symptom score at baseline testing than college-aged females with no reported history of concussion.

An independent t-test was conducted using previous concussion as the Independent Variable (IV) and ImPACT symptom score as the Dependent Variable (DV) to determine if the two groups differed on symptom severity at baseline testing. Levene's test for equality of variance was not significant for this variable. No significant difference between concussed college athletes and non-concussed college athletes was found on total symptom score, $t(26) = .08$, $p > .05$.

Hypothesis 3a. High school females with a history of one or more concussions will earn lower processing speed, visual and verbal memory composite scores and exhibit slower reaction times on ImPACT baseline testing than college-aged females with a history of one or more concussions.

Independent t-tests were conducted using education level as the IV and ImPACT scores as the DV to determine if the two groups differed on measures of visual motor speed, verbal memory, visual memory, and reaction time. Levene's tests for equality of variance were not significant for these variables. No significant differences between concussed high school athletes and concussed college athletes were found for visual motor speed, $t(8) = .02$, visual memory, $t(8) = -.25$, verbal memory, $t(8) = 1.37$, or reaction time, $t(8) = -1.29$, $p > .05$.

Hypothesis 3b. College-aged females with a history of one or more concussions will report a lower total symptom score at baseline testing than high school females with a history of one or more concussions.

An independent t-test was conducted using education level as the Independent Variable (IV) and total symptom score as the Dependent Variable (DV) to determine if the two groups differed on symptom severity at baseline. As reported previously, athletes in the two groups were similar in height and weight, but they differed by age, as expected, given their educational status. Levene's test for equality of variance was not significant for this variable. No significant difference between concussed high school athletes and concussed college athletes was found on total symptom score, $t(8) = .45$, $p > .05$.

Although the analysis found no significant difference between college athletes and high school athletes on total symptom scores, high school athletes did report an average symptom severity score of 7.0 compared to their college-aged counterparts' report of an average symptom severity score of 4.8.

CHAPTER FIVE

Discussion

The current study examined a history of prior SC in high school and collegiate female athletes on baseline ImPACT performance in an effort to determine if prior SC impacted performance on neurocognitive measures and symptom burden. Overall, no significant differences were observed between high school or collegiate females with and without a history of SC on ImPACT performance or in terms of symptom burden during the baseline assessment. Additionally, the current study examined if there were differences by age between high school and collegiate female players on baseline neurocognitive measures and symptom burden. When comparing high school and collegiate athletes with a history of SC, no significant differences were observed in terms of ImPACT performance or symptom burden.

In terms of comparing high school and collegiate athletes with and without a history of SC, we observed no differences for ImPACTs Visual and Verbal Memory, Visual Motor Speed, or Reaction composite scores. Consistent with our findings are those by Mannix et al. (2014) who reported a history of SC does not affect performance on neurocognitive testing measures. Similar to the current study, the authors administered ImPACT prior to the start of their subjects' respective sport seasons and collected a self-reported history of SC. A potentially confounding factor in the current study as well as that by Mannix et al. (2014) is the homogeneity of self-reported concussion history when the majority of participants only reported one concussion. This limited exposure to SC may have limited the potential influence of SC on ImPACT performance, which has been suggested in related literature (Brooks et al., 2013; Iverson et al., 2006). Athletes with a history of more than one SC have been demonstrated to show impaired neurocognitive test performance and the potential neurocognitive deficits as reported in related literature may not be present or measureable in athletes with a history of only one concussion (Covassin et al., 2010; Iverson et al., 2006; Wall et al., 2006).

In contrast to our findings, Colvin et al (2009), observed males and females with a history of one concussion achieved lower scores on ImPACTs Reaction Time and Visual Motor Speed outcome scores. Methodologically, Colvin et al (2009) examined a combined sample of males and females, which may explain the variable results between the previous and current study. In related literature, a history of SC has been reported to result in decreased attention span (Parks et al., 2015), accuracy, verbal memory and impaired task switching behaviors (Covassin et al., 2013; Ellemberg et al., 2007). Our findings may differ from those of related literature due to varying sample sizes, the use of male and female athletes, and varying or more sophisticated neurocognitive and electrophysiological measures, such as the ones Parks et al. (2015) employed in their study.

Similar to the absence of neurocognitive deficits, we observed no difference in symptom burden between high school and collegiate athletes with and without a history of sport concussion. Our findings differ from previous findings reported in related literature. Mannix et al. (2014) reported athletes with a history of SC endorsed a higher symptom burden than those without a history of concussion. Similarly, Colvin et al. (2009) and Brooks et al. (2015) reported that athletes who reported a history of one or more concussions endorsed more symptoms.

In a related study, Iverson et al (2004) compared athletes with a history of three or more concussions to athletes with no prior history of injury. Prior to the start of their respective season, athletes reported a greater number of concussive symptoms compared to athletes without a history of concussion. Our current study focused on total symptom severity rather than the number of symptoms reported by our participants. Additionally, unlike the previous literature, our sample reported a fewer number of concussions compared to the previously mentioned studies which may have resulted in our current findings.

In terms of comparing collegiate female athletes to high school female athletes with a history of concussion, we did not observe a difference in either ImPACT performance or total symptom burden. Few studies have compared female athletes with a history of concussion at the high school and collegiate levels of sport. That said, Covassin et al (2012) reported that female athletes with a history of multiple concussions performed better than male athletes with an equal number of injuries. A comparison between female athletes with varying levels of concussion was not made in their study. Additionally, our findings suggest there were no differences in symptom burden between high school and collegiate athletes with a history of concussion, which varies from related literature (Iverson et al., 2006). Our results are similar to Kontos et al (2012) who reported that high school and collegiate athletes would report similar levels of symptom severity prior to a SC.

An interesting finding of the current study unrelated to self-reported symptomology or cognitive performance is that collegiate athletes reported missing fewer games due to SC compared to high school athletes. This observation may be due to several reasons including the available resources (human, clinical tests, financial), the amount of education provided at either setting, provider knowledge of SC, and a more conservative approach may been taken with younger compared to older athletes. Though interesting, limitations such as whether a SC took place within season or outside of season play/practice would also significantly alter the number of games missed due to a diagnosed injury.

Limitations and Future Research

Our study is not without its limitations. First, a small sample size most likely resulted in underpowered results. Future research should address this issue with a larger cohort of female athletes at the collegiate and high school levels of sport. Next, SC history was based on self-report, which leads to a subjective recall of past injuries. Additionally, athletes may have under- or over-reported the number of injuries sustained due to a lack of an athlete's knowledge about the symptoms of a concussion, not wanting to removed from play, being perceived as weak, and not wanting to let a coach or parent down. Last, our sample had a limited number of diagnosed concussions. As previously mentioned, similar studies included groups with three or more concussions where the majority of our participants had solely one concussive injury, which may have influenced our results.

Conclusion

Our study suggests that female athletes at the high school and collegiate levels of sport did not differ in neurocognitive performance or symptom reporting compared to athletes without a history of SC. Future research using a larger sample of collegiate and high school athletes should be performed examining these important topics in order to provide greater insight into the female athlete and SC in order to provide better care and patient outcomes following injury.

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Table 1

Physical Characteristics (Means and SDs) for Sample Subgroups

	High School Athletes		College Athletes	
Variables	Previous SRC n = 5	No SRC n = 5	Previous SRC n = 14	No SRC n = 14
Age	16.48 (1.02)	16.55 (1.01)	19.42 (0.89)	19.37 (1.09)
Height	68.00 (2.35)	66.20 (1.48)	68.71 (2.09)	67.36 (4.27)
Weight	137.40 (21.54)	136.20 (18.98)	147.79 (22.71)	150.93 (18.03)

Table 2

Physical Characteristics (Means and SDs) for Selected Sample of Concussed Athletes

Variables	High School Athletes n = 5	College Athletes n = 5
Age	16.48 (1.02)	19.79 (0.95)
Height	68.00 (2.35)	67.80 (3.11)
Weight	137.40 (21.54)	144.80 (18.23)

Table 3

Means (SDs) and Percentiles for High School Athletes ImPACT Scores, by Group

Variable	Previous SRC		No Previous SRC		*t* value	*p* value
	n = 5	%	n = 5	%		
Verbal Memory	90.00 (7.97)	61st	87.80 (10.38)	49th	0.37	0.71
Visual Memory	67.80 (19.49)	34th	72.40 (17.46)	49th	-0.39	0.70
Visual Motor Speed	39.47 (7.70)	58th	40.25 (6.61)	65th	-0.17	0.86
Reaction Time	0.56 (0.06)	70th	0.53 (0.03)	79th	0.63	0.54
Total Symptom	7.00 (6.89)	40-75	3.40 (2.30)	40-75	1.10	0.30

Table 4

Means (SDs) and Percentiles for College Athletes ImPACT Scores, by Group

Variable	Previous SRC		No Previous SRC		*t* value	*p* value
	n = 14	%	n = 14	%		
Verbal Memory	87.00 (8.68)	59th	84.86 (12.91)	50th	0.56	0.61
Visual Memory	75.64 (10.51)	55th	67.14 (14.47)	33rd	1.78	0.09
Visual Motor Speed	39.57 (4.85)	47th	38.95 (7.68)	47th	0.26	0.80
Reaction Time	0.57 (0.05)	45th	0.57 (0.06)	41st	-0.29	0.76
Total Symptom	3.29 (6.11)	32-75	3.43 (3.43)	32-75	0.13	0.94

Table 5

Means (SDs) and Percentiles for Athletes with Previous SRC ImPACT Scores, by Group

Variable	College Athletes		High School Athletes		*t* value	*p* value
	n = 5	%	n = 5	%		
Verbal Memory	90.00 (7.97)	73rd	81.20 (11.76)	32nd	1.38	0.20
Visual Memory	67.80 (19.49)	31st	70.20 (9.58)	40th	-0.24	0.81
Visual Motor Speed	39.48 (7.70)	47th	39.40 (4.57)	45th	0.01	0.98
Reaction Time	0.55 (0.60)	56th	0.60 (0.05)	30th	-1.21	0.25
Total Symptom	7.00 (6.89)	32-75	4.80 (8.67)	40-75	0.44	0.66

BIOGRAPHICAL SKETCH

Brandy Borque
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EDUCATION/TRAINING

INSTITUTION AND LOCATION	DEGREE	YEAR(s)	FIELD OF STUDY
University of TX at Tyler	B.A.	2012	Psychology
The University of Texas Southwestern School of Health Professions	M.C.R.C.	2016	Clinical Rehabilitation Counseling

Positions and Employment

2016 Texas Council on Offenders with Medical & Mental Illness (TCOOMMI) Unit Intensive Case Manager contracting out of the Andrews Center
2015 UTSW Supported Employment Services Student Vocational Coach

Clinical Experience

2014 -2015 Supported Employment Services
2014-2015 University Rehabilitation Services
2013 - 2014 Functional Counseling Services—Pate Rehabilitation at Brinlee Creek

Professional Memberships

2015 – 2016 Genesis Women's Shelter—Board Member
2014 – 2016 Alpha Eta Honor Society
2012 - 2016 National Rehabilitation Association
2012 – 2016 Texas Rehabilitation Association—Current Board Member
2012 – 2016 North Texas Area Rehabilitation Association—2015 President
2012 – 2016 International Honor Society in Psychology (Psi Chi)
2010 – 2016 Down Syndrome Guild Member—Dallas

Awards

2014 Schermerhorn Scholarship Recipient
2014 Alpha Eta Honor Society Inductee
2012 International Honor Society in Psychology (Psi Chi) Inductee