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INVESTIGATING THE UTILITY OF PROTECTIVE SOCCER HEADBANDS IN PRESERVING NEUROCOGNITIVE FUNCTION FOLLOWING AN ACUTE BOUT OF SOCCER HEADING

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INVESTIGATING THE UTILITY OF PROTECTIVE SOCCER HEADBANDS IN PRESERVING NEUROCOGNITIVE FUNCTION FOLLOWING AN ACUTE BOUT OF SOCCER HEADING

By

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ABSTRACT

INVESTIGATING THE UTILITY OF PROTECTIVE SOCCER HEADBANDS IN PRESERVING NEUROCOGNITIVE FUNCTION FOLLOWING AN ACUTE BOUT OF SOCCER HEADING

By

Amanda M. Riesterer

Purpose: The purpose of this study was to investigate the utility of protective soccer headbands in preserving neurocognitive function following an acute bout of soccer heading in collegiate soccer players.

Methods: A total of 25 participants volunteered for this study. Participants headed a soccer ball with and without the use of a protective soccer headband. ImPACT was utilized to assess neurocognitive function before and after the acute bout of heading.

Results: Participants in the headband group performed significantly worse on verbal memory after completing the heading exercise. Participants in the no headband group demonstrated faster reaction time than the headband group following the heading exercise.

Conclusion: The use of protective headbands may have facilitated a greater transfer of force to the participants head, causing decrease in neurocognitive function. These results do not support the use of protective headbands as a means to reduce the risk of injury for soccer athletes during heading. The current findings offer more information to the consumer that allows for them to be more educated when deciding to purchase and use a protective headband for soccer

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TABLE OF CONTENTS

LIST OF TABLES

Table

LIST OF FIGURES

Figure

CHAPTER 1

INTRODUCTION

Overview of the Problem

Sports participation carries the inherent risk of injury. An estimated 300,000 sports-related concussions occur annually in the United States (Thurman, Branche & Sniezek, 1998). As the popularity of soccer grows in the United States, so does the risk of soccer related head injury. Concussions have been reported to constitute 2% to 22% of all soccer injuries (Barnes, Cooper, Kirkendall, McDermott, Jordan, & Garrett, 1998; Boden, Kirkendall, & Garrett, 1998). A unique feature of the game of soccer is that athletes may intentionally use their head to play the ball. While heading is a skill that can be an asset, it may also have neurocognitive consequences. Soccer players are likely to sustain numerous impacts from intentional heading of a soccer ball (Tysvaer & Storli, 1981). As a result, the most recent addition to head injury prevention is the soccer headband. Manufacturers claim headbands will decrease the force of head impacts and protect the soccer athlete from the devastating consequences of head injury (Full90, 2007). However, few studies to date have been conducted to evaluate the effectiveness of these headbands.

The few studies that have been conducted to evaluate the utility of soccer headbands have lacked consistent results (Broglio, Ju, Broglio & Sell, 2003; Withnall, Shewchenko, Wonnacott & Dvorak, 2005). For example, Broglio et al. (2003) found that the headbands are effective in reducing the peak force impact of a soccer ball during ball-to-head impacts. In a more recent study, Withnall et al. (2005) found the headbands to be effective in reducing head-to-head impact; yet the headbands did not provide protection from ball-to-head impact.

While the existing literature has evaluated the utility of the soccer headband's ability to dissipate force, no research has been done on the utility of these headbands on preserving neurocognitive function after an acute bout of heading. The debate on whether or not protective headgear should be mandated in soccer will continue until a more definite conclusion can be determined through research. In order to make a decision on this matter, the effectiveness of the headgear in reducing neurocognitive impairment needs to be evaluated in humans.

Significance of the Problem

Soccer has grown to be the most popular and frequently played sport in the world, with more than 200 million participants worldwide (Dvorak & Junge, 2000), many of whom began playing at a very young age. Soccer players may be exposed to concussion and numerous head impacts from heading a soccer ball during their career. In a career of 300 games, a soccer player sustains an estimated 2,000 impacts to the head from heading a soccer ball (Tysvaer & Storli, 1981).

The effects of heading a soccer ball have been proposed to be associated with Chronic Traumatic Brain Injury (CTBI) resulting from the cumulative effects of repetitive concussive and sub-concussive blows to the head (e.g., heading a soccer ball) (Matser, Kessels, Lezak, Jordan & Troost, 1999). Studies have shown that an increased number of headers and concussions are related to poorer memory, planning and visuoperceptual performance (Matser, Kessels, Jordan, Lezak & Troost, 1998). Averaging 8.5 headers per game, amateur soccer players have been shown to score 39% lower than normative values on planning tasks of neurocognitive function (Matser et al., 1999). Matser, Kessels, Lezak and Troost (2001) found that as the number of headers (per 1,000) increased, scores for verbal memory, visual memory and focused attention decreased in a sample of professional soccer players. Similarly, as the number of concussions increased, visuoperceptual processing and sustained attention scores also decreased in this sample (Matser et al., 2001). These findings suggest that neurocognitive impairment in soccer could be caused by a combination of concussions and heading a soccer ball (Matser et al., 1998, 1999, 2001). However, these studies did not employ baseline testing protocols and failed to control for confounding variables (e.g., alcohol and drugs) that may affect neurocognitive function.

There have been several studies that have evaluated the ability of soccer headbands to reduce forces to the skull and brain that are associated with heading a soccer ball. Broglio et al. (2003) used a vertical force platform to evaluate the utility of soccer headbands when confronted with a 35 mph ball impact. The findings found protective headbands to be effective in reducing the peak force impact of a soccer ball during ball-to-head impacts. However, this study used a force platform with a flat surface, which is not similar to the shape of a human head. More recently, Withnall et al. (2005) examined the effectiveness of protective headbands in reducing force during ball-to-head and head-to-head contact. The protective headbands were effective in reducing head-to-head impact; but did not provide protection from ball-to-head impact (Withnall et al., 2005). These studies were limited to using flat force platforms, or dummy head forms to assess peak force, and failed to consider neck strength and human reactions upon impact.

Efforts are being made to protect soccer players from the risk of head injury by utilizing protective headbands. However, it is important to consider the possibility for this equipment to influence game outcomes by altering heading ball control and player comfort. Some researchers suggest that soccer players may get a false sense of security while wearing the protective headband and become aggressive when heading, thereby increasing their risk of injury (Broglio et al., 2003). Similar effects have also been seen in youth rugby players who wear protective helmets. Research suggests that some children display increased risk taking behavior, therefore increasing their risk of sustaining a head injury by wearing a helmet (McCrory, Collie, Anderson & Davis, 2004).

Overall the research that has examined the utility of protective headbands in soccer, and the potential effects of heading on neurocognitive function has yielded conflicting results. There is a need for research efforts to consider these two areas together. The present study will evaluate the utility of a Full 90 soccer headband as a means to protect collegiate soccer players from neurocognitive impairment following an acute bout of heading a soccer ball. The results of this study will be useful to soccer players, coaches, parents, and sports medicine personnel. This study will also aid soccer association personnel in the decision of whether or not to make headbands mandatory equipment for players. This information will also be useful for the National Athletic Trainers' Association (NATA) to further evaluate their position on the use of protective soccer headbands. Currently, the NATA does not support nor discourage the use of protective headbands during practice and/or games, citing that there is no evidence to support their use (Guskiewicz, Bruce, Cantu, Ferrara, Kelly, McCrea et al., 2004). Finally, parents and soccer players will be informed with useful information on making the decision to wear soccer headbands regardless of association rules.

Purpose Statement

The purpose of this study was to investigate the effects of heading and protective headbands on neurocognitive function following an acute bout of soccer heading exercises in collegiate soccer players.

Hypothesis

There will be no difference on measures of neurocognitive function between collegiate soccer players who wear headbands and do not wear headbands after an acute bout of repetitive soccer heading.

Definition of Terms

<u>Chronic Traumatic Brain Injury (CTBI)</u>: a long term neurological impairment typically associated with boxing. It is defined as the cumulative effects of repetitive concussive and sub-concussive blows to the head (Matser et al., 1999).

Concussion: a complex pathophysiological process affecting the brain, induced by traumatic biomechanical factors (Aubry, Cantu, Dvorak, Graf-Baumann, Johnston, Kelly et al., 2002)

Immediate Post-Concussion Assessment and Cognitive Testing (ImPACT): a computerized neuropsychological test battery designed to assess sports-related concussion.

Sub-Concussive Impact: low level head impact which does not elicit concussion symptoms.

Soccer headband: a padded headband worn by soccer players to reduce the effects of head impacts.

Heading: the intentional use of the head to pass, advance or shoot a soccer ball.

Verbal Memory: recall of word lists (Kolb & Wishaw, 2003)

Visual Memory: recall of geometric shapes and faces (Kolb & Wishaw, 2003)

Reaction Time: the time between the onset of a stimulus and the beginning of a movement response (Haywood & Getchell, 2005).

Neurocognitive Function: The ability to use reasoning, judgment, memory, and perception effectively and in a timely manner (Saladin, 2001).

Full90 Sports, Inc: manufacturer of the Full90 headband.

CHAPTER 2

REVIEW OF LITERATURE

Concussion background

There is no general consensus on the definition of concussion by clinicians and researchers. A universal definition would allow for better management of concussion because definition often determines management. The root of the word concussion is the Latin word "*concuss*", which means "to shake violently" (Cantu, 2001). More than 40 years ago, the Committee on Head Injury Nomenclature defined a concussion as "a clinical syndrome characterized by immediate and transient impairment of neural function, such as an alteration of consciousness, disturbance of vision and equilibrium due to brain stem involvement" (Congress of Neurological Surgeons, 1966). This definition was widely accepted, however it did not account for some of the common symptoms of concussion. The Traumatic Brain Injury Act of 1996 introduced the term traumatic brain injury (TBI). Since then the term cerebral concussion and mild traumatic brain injury (MTBI) have been used interchangeably (Maroon, Lovell, Norwig, Podell, Powell & Hartl, 2000). Most recently, the Concussion in Sport Group (CISG) was formed to transcend the limitations of past definitions and defined concussion as "a complex pathophysiological process affecting the brain, induced by traumatic biomechanical forces" (Aubry et al., 2002).

The CISG identified symptoms associated with concussion. A player does not need to have loss of consciousness to have suffered a concussion. However, loss of consciousness is considered a major sign in detecting severity of concussion. Other typical symptoms include headache, dizziness, nausea, loss of balance, confusion, amnesia, feeling dazed, seeing flashing lights, ringing in the ears, double vision and fatigue or sleepiness (Aubry et al., 2002).

Pathophysiology of Concussion

Physiologically, concussion symptoms and cognitive deficits are caused by a neuronal dysfunction. Immediately after injury to the brain, a complex sequence of ionic, metabolic and physiological events occur. The series of physiologic events begins with the binding of excitatory neurotransmitters, an efflux of potassium ions, and an influx of calcium ions which causes depolarization of the neuron (Giza & Hovda, 2001). The sodium-potassium pump works overtime in an attempt to restore the resting membrane potential. This causes the neuron to use additional adenosine-triphosphate (ATP) generating a dramatic jump in glucose metabolism. This hyper-metabolism causes a cellular energy crisis of glucose supply and demand, leaving the brain vulnerable to a second injury. Later physiological changes include delayed cell death and impaired neural connectivity. These metabolic changes alter cognitive function and are linked to the presence of post-concussive symptoms (Giza & Hovda, 2001). Researchers, however, are unable to match clinical findings with specific physiological changes (Giza & Hovda, 2001). Furthermore, physiological changes occurring during a concussion have only been researched on animal models and not on human brains.

Mechanism of Concussion

Some of the mechanisms of concussion injury are coup, contrecoup, rotational and acceleration-deceleration. A coup injury is sustained beneath the point of cranial impact, and occurs most commonly when the head is stationary (Guskiewicz et al., 2004). This type of injury is seen when a football player collides helmets with another player. When an accelerating head impacts a stationary, unyielding object, the brain lags behind and squeezes cerebrospinal fluid toward the site of impact creating a cushion. Upon impact, the brain then shifts causing injury opposite the side of cranial impact known as a contrecoup injury (Guskiewicz et al., 2004). An example of a contrecoup injury is when a soccer player collides with the goalpost. Rotational injuries are seen in sports such as boxing where the hook punch causes the head to rotate after impact. Contact sports are especially likely to have a high occurrence of acceleration-deceleration injuries (Guskiewicz et al., 2004). Acceleration-deceleration injuries occur when the body and head are moving and strike an object, for example, when an ice hockey player body checks another player.

Types of Brain Injuries

To this point, concussion (MTBI) has been the focus of this paper. MTBI has been defined as "a complex pathophysiological process affecting the brain, induced by traumatic biomechanical forces" (Aubry et al., 2002). However, there are other types of brain injury associated with head impacts. Chronic traumatic brain injury is a cumulative condition resulting from repeated concussive and sub-concussive blows to the head (Matser et al., 1999). Neurocognitive functioning has been shown to be inversely related to the number of concussive and sub-concussive impacts sustained by an athlete (Matser et al., 1998, 1999, 2001). Other conditions resulting from cranial impact are epidural and subdural hematomas. They are differentiated by the location of blood accumulation. An epidural hematoma is an accumulation of blood between the dura and the skull. Conversely, a subdural hematoma is an accumulation of blood between the brain and the dura (Besenski, 2002).

Post-Concussion Syndrome

Following any head injury, the possibility exists that post-concussion syndrome will develop. Post-concussion syndrome is typically seen in patients who have been involved in motor vehicle accidents but can develop in athletes, especially those who have a history of repeated concussions (Bailes & Cantu, 2001). Symptoms experienced with post-concussion syndrome can include persistent headache, irritability, dizziness, memory impairment and fatigue. Post-concussion syndrome may also cause decreased cognitive function, decreased sense of physical well-being and mood disturbances (Bailes & Cantu, 2001). Sterr, Herron, Hayward and Montaldi (2006) studied 38 patients with a single MTBI and compared them with matched controls. Eleven of the 38 participants were found to suffer from post-concussion syndrome, and symptom severity was shown to correlate with poor cognitive test performance (Sterr et al., 2006).

Multiple Concussions

An athlete who has suffered a concussion is three to six times more likely to suffer a second concussion during the same season (Collins, Grindell, Lovell, Dede, Moser et al., 1999; Guskiewicz, Weaver, Pauda & Garrett, 2000; Zemper, 2003). Long-term neuropsychological impairments are rarely associated with a single concussion; however multiple concussions have shown detrimental effects of athletes participating in soccer (Matser et al., 1999). Immediate Post-Concussion Assessment and Cognitive Testing (ImPACT) has been used to identify cumulative effects of head injury. For example, Iverson, Gaetz, Lovell and Collins (2004) assessed how multiple concussions affect neurocognitive function. Baseline and post injury ImPACT testing was administered to all participants of the University of Pittsburgh Medical Center Sports Concussion program. A sample of 19 high school and collegiate athletes with three or more concussions were closely matched with athletes who had no history of concussion. Results showed that athletes with multiple concussions are 7.7 times more likely to show a major drop in memory performance than athletes with no previous concussion history. These findings suggest that athletes with multiple head injuries demonstrate cumulative neurocognitive deficits (Iverson et al., 2004).

Grading Scales

There has been an abundance of grading scales and guidelines developed in attempts to classify and determine severity of concussion. The most commonly used scales are the Colorado Medical Society, the Cantu Grading System, and the American Academy of Neurology (ANN) grading scale (see Table 2-1). These, like most scales developed, use loss of consciousness and amnesia as the focal point in the grading scales. These scales are limited because a concussion can present without loss of consciousness or amnesia (Bailes & Cantu, 2001).

The first International Conference on Concussion in Sport and the CISG recommended abolishing grading scales. The 2nd International Conference on Concussion in Sport was held in Prague, Czech Republic and aimed to make advancements on the recommendations put forth by the CISG. The most significant development of the conference is the classification of a concussion as simple or complex. According to the guidelines, a simple concussion is one that gradually resolves without complications within 7 to 10 days. Athletes sustaining a simple concussion will often return-to-play without any further complications. Complex concussions refer to concussed athletes who experience persistent symptoms at rest and during exertion, concussive convulsions, prolonged loss of consciousness (more than one minute), or prolonged cognitive impairment (McCrory, Johnston, Meeuwisse, Aubry, Cantu, Dvjorak et al., 2005). Athletes will also be classified as sustaining a complex concussion if symptoms last longer than 10 days or have a history of concussion.

Table 2-1 *Concussion Grading Scales*

Scale	Grade 1	Grade 2	Grade 3
AAN	Confusion; no loss of consciousness; symptoms last less than 15 min.	Confusion; no loss of consciousness; symptoms last longer than 15 min.	Loss of consciousness
Colorado Medical Society	Confusion; no loss of consciousness; no amnesia	Confusion; no loss of consciousness; amnesia	Loss of consciousness
Cantu	No loss of consciousness; posttraumatic amnesia last less than 30 min.	Loss of consciousness for less than 5 min.; posttraumatic amnesia lasts 30 min-24 hours.	Loss of consciousness for 5 min. or more; posttraumatic amnesia for 24 hours or more.

Return-to-Play

Similar to the inconsistencies of determining severity of injury, there is little conformity on the return-to-play criteria. Throughout the many guidelines developed for return-to-play, the common theme agreed upon by clinicians and researchers is that the athlete should be symptom free before returning to participation (Guskiewicz et al., 2004; McCrory et al., 2005). The three most common return-to-play guidelines are the AAN, Colorado Medical Society, and Cantu (see Table 2-2). The CISG and Prague group proposed a six step process to determining return-to-play. The athlete should proceed to the next step of the process if asymptomatic at the current level. Level 1 is no activity and complete rest. Level 2 includes light aerobic activities such as walking and cycling. Level 3 involves sport specific training. In level 4, the athlete is allowed non-contact training drills. Level 5 introduces full contact training, provided the athlete receives medical clearance. Finally, level 6 is return to game play. If an athlete exhibits any concussion symptoms they must return to the previous step for 24 hours or until symptom free (McCrory et al., 2005).

Table 2-2 *Return-to-Play Guidelines*

Scale	Grade 1	Grade 2	Grade 3
AAN	Same day return if asymptomatic within 15 minutes	Disallow same day return; return in 1 week if asymptomatic	Transport to hospital; observe overnight; return after 1 week (if LOC was brief) or 2 weeks (if LOC was prolonged)
Colorado Medical Society	Evaluate every 5 minutes; Same day return if amnesia or symptoms do not appear for 20 minutes	Disallow same day return; evaluate next day and allow return in 1 week if asymptomatic	Transport to hospital; observe overnight; return in 2 weeks if asymptomatic
Cantu	Same day return in select situations if asymptomatic at rest and during exertion; if symptomatic, may return in 7 days	Return in 2 weeks if asymptomatic at rest and exertion for 7 days	Return in one month if asymptomatic at rest and exertion for 7 days

Incidence of Soccer Head Injury

Participation in sport comes with the inherent risk of injury. Soccer is no exception. Concussions have been reported to constitute 2% to 22% of all soccer injuries (Barnes et al., 1998; Boden, Kirkendall & Garrett, 1998). Barnes et al. (1998) examined 144 men and women soccer players competing in the 1993 U.S. Olympic Festival in San Antonio, Texas. Athletes reported previous concussion symptoms and their frequency of heading the ball during practice and games. Results revealed male soccer players were 2.16 times at a higher risk for sustaining a concussion than female soccer players. Results indicated 89% of male soccer players and 43% of female soccer players experienced a head injury during their career. The most common symptoms reported were headaches, 'dazed,' and dizziness. The researchers suggest male soccer players are at a 50% and females a 22% chance of sustaining a concussion within a 10-year period.

Boden et al. (1998) examined the mechanism and incidence of concussions in male and female varsity soccer players participating in the Atlantic Coast Conference (ACC). Results indicated 17 (59%) men and 12 (41%) females were diagnosed with concussions over the two seasons studied. Results showed males had a higher incidence of sustaining a concussion than female soccer players. The researchers found a 1.42:1 ratio of concussions for men compared to women.

Other studies have contradicted the idea that males are more likely to sustain a concussion than females. Gessel, Fields, Collins, Dick and Comstock (2007) utilized the High School Reporting Information Online (RIO) and the National Collegiate Athletic Association Injury Surveillance System to assess rates and risk factors for sport-related concussion. Results demonstrated that for high school sports played by both sexes, females sustained a higher rate of concussion, and concussions represented a greater proportion of total injuries than males (Gessel et al., 2007).

Mechanism of Soccer Head Injury

Heading is an integral part of the game of soccer. The head may be used to control, pass or shoot a soccer ball. Previously, older leather balls absorbed water, subsequently increasing the weight of the ball by 20%, potentially making them dangerous for heading the ball (Smodlaka, 1984). Today, players use waterproof, synthetic leather soccer balls. When heading a soccer ball, an athlete should strike the ball with his/her forehead, keep his/her chin tucked to his/her chest, and trunk flexed. Athletes should contract their neck muscles to increase the mass of the contact surface when heading a ball (Kirkendall & Garrett, 2001).

Tysvaer and Storli (1981) estimated that in a career of 300 games, a soccer player would experience 2,000 head impacts from purposely heading a soccer ball. Even with the large amount of head impact, a concussion is not likely to be sustained from purposeful heading of a soccer ball (Pickett, Streight, Simpson & Brison, 2005; Boden, Kirkendall & Garrett, 1998; Andersen, Arnason, Engebretsen & Bahr, 2004). Pickett et al., (2005) examined head injuries in youth soccer players in the emergency department. For their study, head injuries could present as minor injuries such as abrasions and lacerations, or more severe conditions such as concussion or intracranial injury. It was reported that of 235 cases, 65.1% of head injuries were due to contact with another player and 26.4% were from contact with the ball. Heading was reported in only four of the ball contact cases. Of these, only one was classified as a concussion and one as a mild head injury which required neurological investigation (Pickett et al., 2005).

The mechanism most likely to cause head injury is head-to-head contact or elbow-to-head contact (Andersen et al., 2004; Boden et al., 1998). Barnes et al. (1998) reported 68 of 102 concussions resulted from collisions with another player. Only 18 of the reported concussions occurred because of collision with the ball (Barnes et al., 1998). It is important to note that it was not reported whether ball impacts were from purposeful heading or another mechanism such as close range head impact from contact with a kicked ball. In a similar study using collegiate soccer players, Boden et al. (1998) reported 29 concussions over a two year period; however none of them were sustained from intentional heading of the ball.

Chronic Traumatic Brain Injury

CTBI is a long-term neurological impairment resulting from the cumulative effects of repetitive concussive and sub-concussive blows to the head (Matser et al., 1999). CTBI appears to be mainly a cognitive disorder without a related motor component (Rabadi & Jordan, 2001). CTBI has been associated with the onset of dementia-related syndromes in retired professional football players (Guskiewicz, Marshall, Bailes, McCrea, Cantu, Randolph et al., 2005), as well as decreased neurocognitive function in soccer players (Matser et al., 1998, 1999, 2001).

Matser et al. (1998) evaluated the presence of CTBI in professional soccer players. Fifty-three active professional soccer players were compared with elite non-contact sport athletes. Professional soccer players were found to have impaired performance on memory, planning, and visuoperceptual processing when compared to controls. In a similar study, Matser et al. (1999) examined amateur soccer players for the presence of neuropsychological impairment. Thirty-three amateur soccer players were compared with control athletes (swimming and track and field). The participants demonstrated decreased performance on planning and memory tests (Matser et al., 1999). In both studies, scores were also found to be inversely related to the number of concussions and headers incurred by the participants suggesting that participation in soccer is associated with impaired neurocognitive function (Matser et al., 1998, 1999).

Webbe and Ochs (2003) investigated the effects of recency and frequency of heading on neurocognitive performance. Sixty-four male soccer players completed a battery of neuropsychological tests and self-reported heading frequency. Results demonstrated that participants who reported the highest number of headers and experienced heading within the previous 7 days scored significantly lower on neurocognitive tests. It is noted that these results cannot be isolated as strictly ball-to-head contact. However, the authors support the results as evidence that heading is problematic and is cause for transient cognitive impairment (Webbe & Ochs, 2003).

Several researchers have contradicted European studies (Matser et al., 1998, 1999) suggesting no correlation between impairment and heading of soccer ball (Broglio & Guskiewicz, 2001; Putukian, Echemendia, & Mackin, 2000). Putukian, Echemendia and Mackin (2000) examined the acute effects of heading on cognitive function. Fourty-four males and 56 females were administered a brief neuropsychological battery to assess cognitive function before and after two separate practice sessions. Results indicated no significant differenced between pretest and posttest scores for both the heading and non-heading groups. Heading the ball was not associated with acute changes in cognitive function (Putukian, Echemendia & Mackin, 2000).

Broglio and Guskiewicz (2001) examined 91 collegiate soccer players (15.27 years of average soccer experience) and 53 student controls for neuropsychological impairments. Each participant reported his/her SAT score and completed the Weschler Digit Span test, the Trail Making Test Part B, and the Stroop Color Word Test. Results found no differences between soccer players and the control group on all tests. The authors suggest soccer players are not at risk for neuropsychological deficits from heading a soccer ball.

CTBI in soccer continues to be a controversial topic. Since CTBI is not brought on by concussion alone, and concussions are not likely to be sustained from heading, focus has shifted to the subtle yet serious effects of heading in soccer. Much of the attention given to heading stems from media coverage of the 2002 death of Jeff Astle, a former English international soccer player. The coroner who examined Astle suggested that the repeated heading of balls during Astle's career contributed to his neurological decline and eventually his death (McCrory, 2003; Eaton, 2002). Prior to Astle's death, Billy McPhail, a former professional soccer player claimed that his Alzheimer's disease was caused by repeated heading of the old-fashioned leather soccer balls. At the time McPhail failed to prove that his condition was caused by playing soccer, however, the coroners ruling in Astle's death is sure to encourage similar injury claims (Rutherford, Stephens & Potter, 2003).

When discussing head injury, soccer is often compared to contact sports such as football and ice hockey. In order to compare soccer with other contact sports, Autti, Spila, Autti and Salonen (1997) studied male amateur soccer and football players using magnetic resonance imaging (MRI). When compared to football players with the same number of concussions, soccer players showed more abnormalities on MRI. The increased abnormalities are believed to be caused by sub-concussive blows experienced when heading a soccer ball (Autti et al., 1997; Matser et al., 2001). Similar findings were present when soccer players were evaluated using electroencephalography (EEG). Increased EEG abnormalities were observed when soccer players were compared with matched controls. The authors suggest neuronal damage was caused by the repetitive minor head traumas experienced while heading a soccer ball (Tysvaer & Storli, 1989).

Effectiveness of Soccer Headbands

The latest equipment aimed at decreasing head injuries is the soccer headband. Since the inception of these headbands there has been question as to their ability to attenuate head impacts. Broglio et al. (2003) tested three different brands of soccer headbands (Headers, Headblast, and Protector). Using a vertical force platform with the headbands attached, a JUGS Soccer

Machine™ was used to propel balls at 35 mph. A significant reduction in peak force of impact was seen in all three brands of soccer headbands. This would lead the public to believe that soccer headbands would reduce the peak force experienced during head impact. However, the study had a major methodological flaw. The force platform that was used was flat, and did not adequately represent a human head. Therefore, research is needed to determine if headbands decrease the peak force during heading a soccer ball on human subjects.

Expanding on the limitations of Broglio et al. (2003), Withnall et al. (2005) tested three different brands of soccer headbands (Full90, Headblast, and Kangaroo). The headbands were placed on dummy headforms and balls were projected at the dummy headforms three separate times at 10 to 30 m/s. In addition, head-to-head impacts were tested by dropping one headform onto another at a speed of 2 to 5 m/s. Results showed that soccer headbands provided a 33% reduction in head-to-head impacts. However, the soccer headbands did not reduce the impact during ball-to-head contact. In fact, during the highest speed tested (30 m/s) the ball-to-head impact was slightly worsened by the use of the soccer headband (Withnall et al., 2005).

Most recently, protective headbands have been evaluated for their ability to decrease the risk of injury associated with playing soccer. Delaney, Al-Kashmiri, Drummond and Correa (2008) utilized a self-reported symptoms questionnaire to investigate the effects of protective headgear in adolescent soccer players. Results demonstrated that only 26.9% of athletes who wore the headgear sustained a concussion. However, 52.8% of athletes who did not wear the headgear sustained a concussion. Other results showed that athletes who wore the protective headgear suffered less abrasions, lacerations and contusions to the area of the head covered by the headgear. The authors concluded that the use of soccer headgear may decrease the risk of sustaining an injury to the head and face (Delaney et al., 2008).

Computerized neurological testing

Neuropsychological testing has evolved from the traditional paper and pencil test to the computerized test. There are currently three commercially available computerized tests used to assess neurocognitive function: ImPACT (University of Pittsburgh, Pittsburgh, PA), CogSport (CogState Ltd, Victoria, Australia), and Headminder Concussion Resolution Index (Headminder, Inc, New York, NY). However, this paper will focus on ImPACT due to the strong association of the university faculty and the testing battery. Detailed information and psychometric properties of ImPACT are covered under the methods/instrumentation section.

Summary

During the 1st International Conference on Concussion in Sport the CISG defined concussion as "a complex pathophysiological process affecting the brain, induced by traumatic biomechanical forces" (Aubry et al., 2002). The 2nd International Conference on Concussion in Sport made advancements on the classification of concussed athletes. Concussions are classified as simple and complex based on the length and type of symptoms that are experienced

(McCrory et al., 2005). In addition to classification, McCrory et al. (2005) sought to streamline the return-to-play criteria. The athlete should be symptom free as he/she moves through each of the six stages. Starting at complete rest, each level adds more activity, ending with unrestricted game play (McCrory et al., 2005). These advancements in definition, classification and return-to-play criteria have been important for researchers and clinicians alike, allowing for a more universal approach to treatment.

Head injury has been shown to constitute 2% to 22% of all soccer injuries (Barnes et al., 1998; Boden, Kirkendall & Garrett, 1998). Concussion in soccer is caused by direct impact with the ground or goalpost, head-to-head or ball-to-head contact. Research suggests that intentional ball-to-head impact, such as heading, is not likely to cause concussion (Andersen et al., 2004; Boden et al., 1998). However, research has suggested that soccer players are at risk of CTBI. Soccer players have exhibited decreased performance on neurocognitive tests as the number of concussions and headers taken increased (Matser et al., 1998, 1999, 2001). However, these studies did not account for drug and alcohol use among the participants. These methodological flaws suggest more research needs to be done on the cumulative effects of heading a soccer ball.

Head impacts in soccer cannot be prevented due to the nature of the game. It is the only sport which allows for the intentional use of the head to pass or shoot the soccer ball. Recently, soccer headbands have been manufactured and marketed toward soccer athletes claiming to reduce the force of head impact in soccer (Full90 Sports, Inc., 2007). There have been several studies that have tested the effectiveness of soccer headbands at attenuating head impacts. Broglio et al. (2003) found that the soccer headbands reduced the peak force of impact when attached to a flat force plate and impacted by a ball at 35 mph. In addition, Withnall et al. (2005) found the headbands to be effective during head-to-head impacts, but not during high speed ball-to-head impacts when tested on dummy head forms. However, these studies did not use humans nor did they test for neurocognitive impairments associated with heading a soccer ball. In order for the public to make an informed decision about purchasing the soccer headbands, neurocognitive impairment must be addressed through research.

CHAPTER 3

METHODS

Research Design

A quasi-experimental pretest/posttest design was used for this study. The independent variables were group (soccer headband (Full90), no headband), testing occasions (baseline, post-test) and soccer heading (15 times). The dependent variables were ImPACT composite scores of verbal memory, visual memory, motor processing speed, reaction time and total reported symptoms.

Participants

Twenty-five varsity and club soccer players, from a major Midwestern Division I university were asked to participate. The ages of participants ranged from 18 to 23 years. Each participant had a minimum of four years experience playing organized soccer. Any participant with a history of concussion (the past six months), learning disability, brain surgery, Attention Deficit Disorder/Attention Deficit Hyperactivity Disorder, colorblindness or chronic migraine headaches were excluded from this study. Participants were randomly assigned to either a headband or no headband group.

Sampling method. A convenience sample was used for this study. Participants were recruited by contacting both varsity and club soccer coaches and subsequently addressing each team to identify athletes who wished to volunteer for the current study

Instrumentation

Immediate Post-Concussion Assessment and Cognitive Testing (ImPACT). ImPACT was used to determine neurocognitive function of each participant before and after the heading exercise. ImPACT is widely used in the recognition and management of concussion in athletes (Van Kampen, Lovell, Pardini, Collins & Fu, 2006). ImPACT consists of three main categories: demographic data, the post-concussion symptom scale (PCSS) and neuropsychological test modules. It is important to note that ImPACT has multiple built-in design/word groups. This is important to limit practice effects. A different word/design group was administered to the participant for each test.

Module 1 of the neurocognitive test battery focuses on word discrimination. This section is used to evaluate verbal memory and attentional processes. Subjects are presented with 12 words two times each for 750 milliseconds. Individuals are then asked to recall words from a 24-word list. There are 12 target words and 12 non-target words. Using the mouse, subjects are prompted to select "yes" or "no" depending on whether or not the word was presented in the original list. At the end of the final composite test battery, subjects are asked again to recall this list of words. A total score of percent correct is calculated from immediate and delayed recall of these items.

Module 2 evaluates attention and visual recognition through design memory. Similar to Module 1, 12 target designs are presented twice for 750 milliseconds. Following the presentation subjects are asked to recall these designs, choosing from the 12 target and 12 non-target designs presented.

Subjects are prompted to click "yes" or "no" depending on whether or not the design was originally presented. At the end of the final composite test battery, subjects are asked again to recall these designs. A total score of percent correct is given at the end of the battery for immediate and delayed recall.

Module 3 measures visual working memory, visual processing speed, and visual memory. This section incorporates a distractor which is a reaction time test that asks the subject to click the left mouse button if a blue square appears, and the right mouse button if a red circle appears. For the memory test, a random assortment of X's and Os are displayed for 1.5 seconds. Of this random assortment, three X's and O's are illuminated in yellow. The subject is instructed to remember the placement of these illuminated objects. Immediately following the presentation of the three illuminated X's and O's, the subject is asked to complete the distractor task. After the completion of the distractor task, the memory screen reappears and the subject is asked to click on the X's and O's that were originally highlighted. Four trials are completed for this section. Scores for this section include percent correct for identification of the X's and O's and also reaction time scores for the distractor task.

Module 4 is a symbol-matching task that evaluates processing speed, learning, and memory. A grid with nine common symbols and accompanying numbers are presented to the subject. The subject is presented with a symbol below the grid, and is asked to click the number of the corresponding design. After 27 trials, the symbols are removed from the grid. The symbols again are presented below the grid, and the subject is asked to recall the correct symbol/number pairing by clicking the appropriate button. Reaction time scores and memory scores are both calculated.

Module 5 measures choice reaction time and impulse control. Subjects are presented with the words red, green and blue each written in their respective color. Subjects are instructed to click the mouse when the word displayed correctly matches the color in which the word is written (i.e. the word "green" written in the color green). For this section a reaction time score is provided and as well as a task error score.

The sixth and final module assesses working memory and visual motor response speeds. This module is comprised of both a distractor task and memory component. Participants are presented with and asked to remember three letters. Once the letters are removed from the screen, the participant is presented with the distractor task. A 5x5 grid appears on the screen consisting of 25 numbered boxes. The participant is asked to count backwards, clicking on the corresponding numbered box with the mouse. Following the completion of the distractor task, the participant then must input the three letters in the exact order they were previously presented. There are five trials for this test module.

Composite scores for verbal memory, visual memory, processing speed, and reaction time were generated from the six neuropsychological testing modules. Sensitivity (the likelihood that the test will be positive when a concussion is present) of ImPACT has been established at 81.9%, and the specificity (the likelihood that the test will be negative when a concussion is not present) has been established at 89.4% (Schatz, Pardini, Lovell, Collins & Podell, 2006). ImPACT has undergone extensive validation through various studies and is widely accepted for use in high school, collegiate and professional sports (Van Kampen et al., 2006; Schatz et al., 2006; Lovell, Collins, Iverson, Field, Maroon, Cantu et al., 2003).

JUGS Soccer Machine. A JUGS Soccer Machine™ was used to propel the soccer balls for the present study. There are two speed dials located on the control panel which set the speed at which two wheels propel the ball. The speed dials allow for consistent ball speed to be achieved. The JUGS Soccer Machine™ has the capability to propel a soccer ball at speeds ranging from 0-100 mph. The ball is placed in the feed chute where it is launched toward the participant at the speed indicated by the speed dials.

Broglio, Guskiewicz, Sell and Lephart (2004) utilized the JUGS Soccer Machine™ to propel soccer balls when evaluating changes in postural control following soccer heading. An exit velocity of 55 mph at a distance of 80 feet was the specific parameters for this heading exercise. Fifty-five miles per hour was found to be consistent with the average corner kick speed for men's and women's intercollegiate soccer teams (Broglio et al., 2004; Kirkendall, Jordan & Garrett, 2001).

Full90 Headband. The Full90 headband has been evaluated for effectiveness on several occasions. Formerly called "Headers", the Full90 headband was shown to reduce time to peak force and impulse when impacted by a soccer ball (Broglio et al., 2003). Withnall et al. (2005) also tested the Full90 headband and found it to be effective during head-to-head impacts.

Interestingly, during high speed (30 m/s) ball-to-head impacts the headband did not provide protection and in some cases made the forces slightly worse (Withnall et al., 2005). In order to further evaluate its effectiveness in ball-to-head impacts, the Full90 headband will be used in this study.

Intervention

Each participant was asked to head a soccer ball 15 times over a 15 minute period, using a proper linear heading technique. This number of headers was established in order to simulate the typical amount of heading done in a day of practice for the participants. Participants in the experimental group completed the heading task while wearing the appropriate size (S, M, or L) Full90 headband (Full90 Sports, Inc. San Diego, CA). The control group (i.e. no headband) performed the heading task without using the soccer headband.

With the participant standing 35 yards away (distance of an average corner kick), a JUGS Soccer Machine™ (JUGS, Tualatin, OR) was used to propel the soccer balls during the heading exercise in order to maintain consistency of ball speed. The soccer balls were inflated to the manufacturer's guidelines of pressure. To reduce the risk of injury and discomfort for the participants, a speed of 50 mph was used. The speed of 50 mph is considered less than the average corner kick speed for collegiate soccer players (Broglio et al., 2004; Kirkendall, Jordan & Garrett, 2001).

Procedures. The researcher obtained human subjects approval from the Michigan State University Institutional Review Board. Written informed consent was obtained from each participant prior to their voluntary participation in this study. Testing did not begin until athletes completed their competitive season and had at least one week of rest from heading a soccer ball. A pilot test was conducted prior to beginning the testing phase of the current study. Additionally, informal feedback from coaches, current players and former players was given regarding the realistic properties of the experimental setting.

Testing Session. Participants reported to the computer testing room on a designated pre-arrange time and day. Written informed consent was completed at this time and each participant was randomly assigned to either the control group or experimental group. Participants were administered a baseline ImPACT test prior to the start of the heading exercise. Participants then reported to a gymnasium, where they were instructed on proper heading technique, and allowed to watch five soccer balls launched, in order to familiarize themselves with the speed of the ball. Participants in the experimental group were fitted with a Full 90 headband. Each participant was then asked to head a soccer ball 15 times over a 15 minute period. A research assistant recorded the heading accuracy for each participant. A correct header was indicated when participants headed the ball off the frontal bone. All other headers (i.e. temporal bone) were counted; however, they were recorded as incorrect. Once the heading exercise was complete, participants were immediately escorted back to the computer testing room for a follow-up administration of the ImPACT test.

Key Personnel. All ImPACT testing was administered by the researcher and by a faculty member who is knowledgeable and experienced in using ImPACT. The JUGS Soccer Machine™ operator was trained prior to the start of the study on how to set the speed and how to propel the ball for each heading exercise. A physician was on-call and a certified athletic trainer was present in case of an emergency.

Data Management

ImPACT data was recorded and kept on a password protected computer in a locked office. Informed consent documents were kept in a folder, in a locked file cabinet in a locked office. Access to the data and informed consent documents was limited to the researcher and faculty advisor. All data were kept confidential and protected in order to protect the privacy of participants and sensitive information.

Data Analysis

ImPACT yields composite scores for verbal memory, visual memory, visual processing speed, and reaction time. A higher score by the athlete on verbal and visual memory, and processing speed indicates better performance. Verbal and visual memory scores are presented as a percentage of 100 and processing speed as a number composite score. A lower score on reaction time indicates better performance.

Demographic information was summarized using descriptive data. A 2 group (headband, no headband), X 2 testing occasions (pre/post test) multivariate analysis of variance (MANCOVA) controlling for concussion history with repeated measures on the last factor was utilized to examine within and between group differences on all ImPACT composite scores. Concussion history was controlled for to eliminate any potential effects that previous concussion may have on performance at baseline or post-heading testing times. The level of significance was set at p = .05. All analyses were conducted using the Statistical Package for the Social Sciences version 15.1 (SPSS, 2005).

Threats to Internal Validity

There are several time threats related to the current study. Maturation threats exist, since the testing will take over an hour to complete. The participants could have become fatigued during the time it took to pretest, complete the heading exercise and posttest especially if they have been physically active on the day of testing. Maturation threats were minimized by scheduling the testing session after the end of the post-season. There should not have been an issue with instrument decay or testing reactivity in this study due to the established validity and reliability of ImPACT. Group threats are unlikely to be an issue because of the random assignment to groups.

Threats to External Validity

A threat to external validity for this study was participant reaction to experimental settings. The heading exercise was controlled by using consistent ball speeds, distance from the JUGS Soccer Machine™ and proper linear heading techniques. In a real life soccer setting, the ball speed would vary, along with the number of headers taken, distance from which the header is taken and the direction of the heading (linear or rotational). In order to minimize the experimental setting threat, the number of headers, ball speed, distance and heading technique were based on norms for the population. The number of headers is based on an average day of practice for the participants, ball speed was chosen because it represents just below the average corner kick speed of a varsity collegiate athlete and a distance of 35 yards represents the average corner kick distance on a soccer field. The other threats to external validity (reaction/interaction effects of testing, multiple treatment interference and interaction of selection bias and treatment) were not a factor for this study because of the use of ImPACT.

CHAPTER 4

RESULTS

The results section is separated into demographic information, baseline data, heading accuracy and evaluation of the research questions. Overall the headband group performed significantly worse on verbal memory after completing the heading exercise. Interestingly, the no headband group demonstrated a faster reaction time than the headband group following the heading exercise.

Demographic Information

A total of 25 varsity and club soccer players (10 males and 15 females) from a Mid-Western Division I-A university participated in the current study. All demographic information was collected by ImPACT. Fourteen participants (5 males and 9 females) were members of the varsity soccer team and 11 participants (5 males and 6 females) were club soccer members. All participants were randomly assigned to either headband or no headband group. There were 12 participants (5 males and 7 females) in the headband group (age= 20.42 ± 1.88 years, height= 67.17 + 4.02 inches, weight= 150.42 + 20.73 lbs.) and 13 participants (5 males and 8 females) in the no headband group (age= 20.08 ± 1.61 years, height= 66.46 ± 3.50 inches, weight= 145.46 ± 17.90 lbs.).

Baseline Data

A MANCOVA controlling for concussion history was used to examine differences in baseline ImPACT composite scores and total symptoms between the headband and no headband groups. Baseline ImPACT composite scores, total symptoms and normative data are presented in Table 4-1. In general, the baseline ImPACT composite scores and symptoms for this sample were average compared to established normative data for this population.

Table 4-1 *Descriptive Baseline ImPACT Composite and Symptom Scores for the Total Sample* (*N*=25)

ImPACT Module	*Mean*	*SD*	ImPACT Norms University Men†	ImPACT Norms University Women†
Verbal Memory	0.88	0.09	0.88	0.92
Visual Memory	0.81	0.12	0.81	0.79
Motor Speed	44.77	6.09	37.25	38.25
Reaction Time	0.54	0.06	0.56	0.55
Symptom Total	2.36	5.16	NA	NA

†Median values of men's and women's ImPACT scores

A comparison of headband and no headband participants indicated no significant differences on baseline ImPACT composite scores and total symptoms between groups (*Wilk's* λ= 0.82, F [5, 18] = 0.79, p= 0.57, η^2= 0.44). Similarly, a comparison of all participants and normative data revealed no significant differences on baseline ImPACT composite scores. The data suggests that participants were similar in regard to baseline ImPACT composite scores and symptoms, regardless of these potential confounding factors. Hence, any differences between baseline and post heading composite scores and symptoms would likely be due to heading.

Heading Accuracy

Proper heading was defined as the intentional impact of a ball on the frontal bone. The number of instances that subjects did not head the ball correctly (e.g., top of head) was recorded by the researcher. Participant statistics for the number of correct headers performed can be seen in Table 4-2. The headband group properly headed an average of 12.83 (*SD*= $\pm$1.70) soccer balls, while the no headband group properly headed an average of 11.70 (*SD*=$\pm$2.63) soccer balls. An independent t-test was performed to examine differences between headband and no headband groups on the number of proper headers. The results indicated no differences between headband and no headband groups on heading accuracy ($t_{(23)}$= 1.28, p=0.21).

Table 4-2 *Mean Correct Headers for Headband (N=12) and No Headband (N=13) Groups*

	Mean	*SD*	*Range*
Headband	12.83	$\pm$1.70	9-15
No Headband	11.70	$\pm$2.63	8-15

Evaluation of Hypothesis

Hypothesis: *There will be no difference on measures of neurocognitive function between collegiate soccer players who wear headbands and do not wear headbands after an acute bout of repetitive soccer heading.* A 2 group (headband, no headband) x 2 time (baseline, post-test) repeated measures MANCOVA controlling for concussion history was used to assess within and between group differences on ImPACT composite scores and total symptoms before and after the heading exercise. Descriptive statistics of each ImPACT composite score and symptom totals can be found in Table 4-3.

Table 4-3 *Baseline and Post Heading Descriptive Statistics for Headband and No Headband Groups on ImPACT Composite Scores and Total Symptoms.*

	Baseline		Post Heading	
	M	*SD*	*M*	*SD*
Verbal Memory				
Headband	0.90	0.09	0.85	0.12
No Headband	0.85	0.10	0.88	0.10
Visual Memory				
Headband	0.83	0.11	0.80	0.12
No Headband	0.79	0.12	0.82	0.10
Processing Speed				
Headband	47.09	5.82	47.81	7.18
No Headband	42.64	5.72	43.02	6.50
Reaction Time				
Headband	0.53	0.06	0.52	0.05
No Headband	0.55	0.05	0.52	0.04
Total Symptoms				
Headband	1.92	2.58	2.00	2.63
No Headband	2.77	6.84	3.46	4.58

The MANCOVA results indicated a significant within subject interaction for group and time (*Wilk's* λ= 0.56, F [5, 18] = 2.81, p= 0.48, η^2= 0.44). A depiction of this interaction can be seen in Figures 1 and 2. Subsequent univariate analyses found significant differences for verbal memory (p=0.02) and reaction time (p=0.03). A series of paired t-tests were performed to further explore this interaction. Results indicated that the headband group performed significantly worse on verbal memory from baseline to post-test ($t_{(11)}$= 2.58, p=0.03). However, there were no significant differences on verbal memory for the no headband group from baseline to post-test ($t_{(12)}$= -1.22, p=0.25). In addition, the no headband group performed significantly faster on ImPACT reaction time from baseline to post-test ($t_{(12)}$= 3.71, p=0.03). In comparison the headband group did not demonstrate a significant difference in performance on reaction time from baseline to post-test ($t_{(11)}$= 0.30, p=0.77). There was no significant difference between groups for visual memory (p=0.26), processing speed (p=0.83) and total symptoms (p=0.64).

Table 4-4 Results *of a Repeated Measures MANCOVA for Within and Between Headband (N=12) and No Headband Groups (N=13) on ImPACT Composite Scores and Total Symptoms.*

Source	*Wilk's λ*	*F*	*Df*	*Error df*	*p*
		Within Subjects			
Time	.78	1.02	5.00	18.00	.44
Time X Headband	.56	2.81	5.00	18.00	.05*
		Between Subjects			
Headband	.79	.94	5.00	18.00	.48

$*p \leq 0.05$

Table 4-5 Univariate Results of ImPACT Composite Scores and Total Symptoms

		df	*F*	*p*
Time				
	Verbal Memory	1.00	.30	.59
	Visual Memory	1.00	1.12	.30
	Processing Speed	1.00	.46	.51
	Reaction Time	1.00	1.78	.20
	Symptom Total	1.00	.38	.55
Time X Headband				
	Verbal Memory	1.00	.02	.02
	Visual Memory	1.00	.01	.26
	Processing Speed	1.00	.54	.83
	Reaction Time	1.00	.00	.03
	Symptom Total	1.00	2.44	.64

$^*p \leq 0.05$

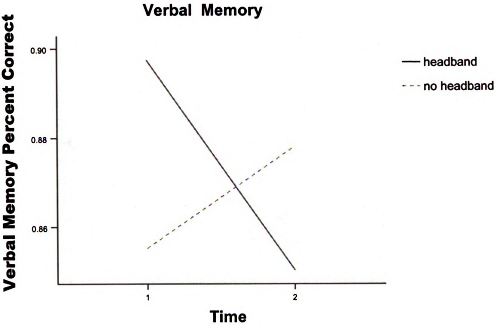

Figure 1 Interaction of Verbal Memory Scores

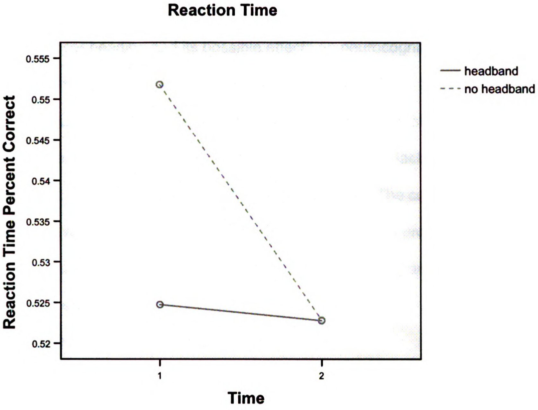

Figure 2 Interaction of Reaction Time Scores

CHAPTER 5

DISCUSSION

Soccer heading and its possible effects on neurocognitive function have been debated in previous studies (Matser et al., 1998, 1999, 2001; Broglio & Guskiewicz, 2001). Furthermore, the studies that have investigated the utility of soccer headbands as effective protective equipment also lack empirical agreement (Broglio et al., 2003; Withnall et al., 2005). The current study adds to the unequivocal nature of the current literature as wearing protective headbands were associated with neurocognitive impairments following an acute bout of heading a soccer ball.

Discussion of ImPACT Composite Scores

Verbal memory composite scores significantly decreased for participants in the headband group following the heading exercise. The verbal memory composite score is derived from immediate and delayed recall tasks, a symbol match task and a three letter recall. In order to better explain why significant declines in neurocognitive function were found in the headband group only, it is imperative that the biomechanical properties of the protective headband are considered during an acute bout of repetitive heading.

The significant change in verbal memory might be explained by the findings of Broglio et al. (2003) who tested several protective headbands including the Full90 (formerly called Headers) using a force platform. Results showed the protective headband demonstrated a greater impulse when compared with the other conditions, indicating the greatest transfer of energy through the headband to a force platform. The Full90 headband also illustrated no difference in peak force when compared with the other headbands, suggesting that the total contact time of the soccer ball with the Full90 headband is greater, which allows for a greater force transfer to the players head.

Another possible explanation for the change in verbal memory may be due to the minimal protection from ball impacts when wearing a protective headband (Withnall et al., 2005). The researchers found in high speed cases (30 m/s), there was an increase in maximum head impact power when testing soccer headbands on dummy headforms. The authors attributed these findings to the deformation of the ball over the protective headband when it impacts the head, stating that in order for the headband to better protect from the deformation of the ball, it would need to be thicker, and likely softer, to successfully reduce the ball impact. They also noted that a thicker, softer headband would almost certainly lead to negative athlete acceptance and reduced heading control and power.

The effects of increased force transfer and ball deformation on brain function must also be considered. Proper heading technique utilizes the frontal bone and a player should strike the ball with his/her forehead at or near the hairline (Kirkendall & Garrett, 2001). Beneath the frontal bone lies the pre-frontal cortex (PFC) of the brain. The PFC plays a critical role in working memory (Mueller, Machado & Knight, 2002). When considering the findings of Broglio et al. (2003) and Withnall et al. (2005) on force transfer of protective headbands, an increased transfer of force to the frontal bone and PFC would compromise the integrity of working memory.

A comparison of pre and post test visual memory, processing speed and reaction time composite scores and total symptoms for the headband group were not significant. These results are in agreement with Guskiewicz et al. (2002) who found no significant decrease in visual memory, processing speed or reaction time when comparing soccer players to control athletes. In addition, a pilot study conducted by Putukian, Echemendia and Mackin (2000) compared heading and non-heading groups using a brief neuropsychological test battery and symptom checklist before and after two separate practices. Results indicated no significant differences on any of these measures of neurocognitive function between groups.

Results of the current study found that participants in the no headband group demonstrated faster reaction time than the headband group following the heading exercise. There is currently no available research to support this finding. This finding could be coincidental as the current study had a small sample size. Further research should be conducted to investigate this finding. However, it should be noted that an improved reaction time supports the idea that heading is not associated with neurocognitive impairment. A comparison of pre and post test verbal memory, visual memory and processing speed composite scores and total symptoms for the no headband group were not significant. This is consistent with earlier studies finding no neurocognitive impairment associated with heading (Guskiewicz et al., 2002; Putukian, Echemendia & Mackin, 2000). The current study also contradicts the findings of Matser et al., (1998) which reported a decrease in memory as the number of headers (per 1,000) increased.

Likewise, Webbe and Ochs, (2003) found an interaction of frequency and recency of heading in male soccer players. Players who reported the highest heading incidence exhibited decreased verbal memory when tested within 7 days of heading.

Clinical Interpretation of Results

Over the past two decades, understanding the possible cognitive effects of repetitive soccer heading has become an interest of both researchers and clinicians. Since their inception, protective soccer headbands have been designed as a means to reduce the forces to the skull and brain that are associated with head impacts from a soccer ball. Results of the current study question the utility of the protective headband in protecting the athlete from neurocognitive deficits following the heading exercise. Furthermore, the use of protective headbands may have facilitated a greater transfer of force to the participants head, causing decrease in neurocognitive function. These results do not support the use of protective headbands as a means to reduce the risk of injury for soccer athletes during heading.

Limitations

The current study is not without inherent limitations to research. The current study had a small sample size which may have contributed to the findings. Participants only included varsity and club soccer players at a single Division I-A institution. Recruiting varying levels and ages of soccer players from many institutions and geographic areas would provide a more diverse soccer population.

The speed of the soccer ball and distance used were just below the average for male and female varsity soccer players. Considering the neck strength differences between men and women and the skill differences between club and varsity players, a preliminary study focusing on average kick speeds and distances should be conducted for each gender and skill level. In addition, participants were asked to linearly head each ball from a set distance and speed. In a competitive setting the ball speed would vary, along with the number of headers taken, distance from which the header is taken, and the direction of heading a soccer ball (linear or rotational).

Future Research Considerations

Future research should consider gender differences, age, and level of ability. Additionally, the effects of heading and the use of soccer headbands on neurocognitive function should continue to be examined by utilizing a soccer game or practice instead of a laboratory setting.

Other directions of research should include examining recovery of possible neurocognitive impairments following heading exercises. The current study can be expanded to include additional testing occasions (e.g., 24 hours) after the heading exercise. This will give better insight into how long the neurocognitive deficits are present after completing the heading exercise.

Conclusion

Computerized neuropsychological testing is becoming a common practice in sports medicine. This study utilized ImPACT to examine the effects of heading and the use of soccer headbands on neurocognitive function. Results of the current study demonstrated neurocognitive impairment on verbal memory composite score following the heading exercise for the headband group. Additionally, the no headband group showed a significant improvement in reaction time following the heading exercise.

The information presented will assist sports medicine professionals with the decision to utilize soccer headbands as a means to protect soccer athletes from head injury. Full90 Sports, Inc. focuses the marketing of protective headbands on head-to-head impacts that occur in soccer. The protective headband has been proven to reduce force transfer associated with head-to-head impacts (Withnall et al., 2005). However the protective headband also demonstrates the ability to cause neurocognitive impairments following an acute bout of repetitive heading. Therefore, the decision now becomes that of the consumer and of sports medicine professionals to use protective headbands to guard players from head-to-head impacts, knowing the headband may facilitate neurocognitive dysfunction after heading a soccer ball. An individual must weigh the benefits and consequences for themselves. Overall, these findings offer more information to the consumer that allows for them to be more educated when deciding to purchase and use a protective headband for soccer.

APPENDIX A

Human Subjects Consent Form

The Effectiveness of Soccer Headbands on Reducing Neurocognitive Impairment Following Soccer Heading Exercises in Collegiate Soccer Players.

Informed Consent

For questions regarding this study, Please contact:
Tracey Covassin Ph.D, ATC
Department of Kinesiology
Michigan State University
Phone: (517) 353-2010
E-mail: covassin@msu.edu or

For questions regarding your rights as a research participant, please contact:
Peter Vasilenko, Ph.D.
Director of MSU's Human Research Protection Programs
Michigan State University
202 Olds Hall
East Lansing, MI 48824
irb@msu.edu
Phone: (517) 355-2180
Fax: (517) 432-4503

1. Purpose of Research:
You are being asked to participate in a research study to determine if repetitive heading in soccer contributes to neurocognitive dysfunction. You have been selected as a possible participant in this study because you participate on a collegiate varsity or club soccer team. From this study, the researchers hope to learn if the Full 90 soccer headband reduces neurocognitive impairments following soccer heading exercises in collegiate soccer players. A secondary purpose is to examine gender differences in neurocognitive function after heading a soccer ball. Your participation in this study will take about 2 3/4 hours to complete. The first session will last approximately 30 minutes, the second session will take approximately 45 minute. The third session will take approximately 20 minutes. The fourth session will take approximately 45 minute. The fifth session will take approximately 20 minutes. You must be 18 years or older to participate in this study.

2. WHAT YOU WILL DO:
The study will use the Immediate Post-Concussion Assessment and Cognitive Testing (ImPACT) computer program as an assessment tool. In this study, ImPACT will be used to test your short and long term memory, concentration level, processing speed, and reaction time. You will complete a baseline ImPACT test approximately one week following the conclusion of your season (session 1). Screening is neither intelligence, nor achievement testing. No invasive procedures are performed.

For session 2, you will be instructed on proper heading technique, and allowed to watch five soccer balls launched, in order to familiarize yourself with the speed of the ball. A JUGS Soccer Machine™ will be used to propel the soccer balls at a speed of 55 mph. You will be randomly assigned to either a control group or an experimental group. If you are in the experimental group you will be fitted with a Full 90 headband. You will then be asked to head a soccer ball 15 times over a 15 minute period. Once the heading exercise is complete, you will be immediately administered a second ImPACT test. For session 3, you will be asked to take ImPACT 24-48 hours following your heading session.

You will have at least 1 week between testing occasions to recovery from any potential effects of the heading exercise. For session 4, you will be assigned to either the control group or an experimental group depending on which group you were randomly assigned to during the second test session. If you are in the control group you will not wear a Full 90 headband for this session. You will be asked to head a soccer ball 15 times over a 15 minute period. Again, a JUGS Soccer Machine™ will be used to propel the soccer balls at a speed of 55 mph. Once the heading exercise is complete, you will be immediately administered a third ImPACT test. For session 5, you will take an ImPACT test 24-48 hours after your heading session.

3. POTENTIAL BENEFITS:
You will not directly benefit from participation in this study. However, information gathered from this study may potentially the effectiveness of soccer headbands on reducing neurocognitive impairment following soccer heading exercises in collegiate soccer players.

4. POTENTIAL RISKS:
You are aware that your participation in the above stated study involves minimal discomfort or harm to you. Please be assured that you may choose to not answer certain questions on ImPACT and still continue to participate in this study. All answers are strictly confidential and will not be released to anyone. You may also choose to not head a soccer ball during this study. If you are injured during heading a soccer ball a certified athletic trainer or team physician will be able to assist you with your injury.

5. PRIVACY AND CONFIDENTIALITY:

The data for this project are being collected anonymously. Neither the researchers nor anyone else (e.g. coaches, athletic trainers) will be able to link data to you. Participation in this study is completely voluntary. You have the right to say no. You may change your mind at any time and withdraw. Confidentiality will be protected by; (a) results will be presented in aggregate form in any presentations and publications; and (b) all data will be stored in a computer that has a password necessary to see confidential data. Your privacy will be protected to the maximum extent allowable by law. You may also discontinue participation at any time without penalty. Your participation in this research project will not involve any additional costs to you or your health care insurer. The results of this study may be published or presented at professional meetings, but the identities of all research participants will remain anonymous.

6. COSTS AND COMPENSATION FOR BEING IN THE STUDY:

Procedures being performed for research purposes only will be provided free of charge by Dr. Covassin and her research assistant. You will not receive money or any other form of compensation for participating in this study.

7. THE RIGHT TO GET HELP IF INJURED:

If you are injured as a result of your participation in this research project, Michigan State University will assist you in obtaining emergency care, if necessary, for your research related injuries. If you have insurance for medical care, your insurance carrier will be billed in the ordinary manner. As with any medical insurance, any costs that are not covered or in excess of what are paid by your insurance, including deductibles, will be your responsibility. Financial compensation for lost wages, disability, pain or discomfort is not available. This does not mean that you are giving up any legal rights you may have. You may contact Dr. Tracey Covassin at 517-353-2010 with any questions.

8. CONTACT INFORMATION FOR QUESTIONS AND CONCERNS

If you have any questions about this study, such as scientific issues, how to do any part of it, or to report an injury, please contact the researcher Dr. Tracey Covassin at 517-353-2010 or e-mail her at covassin@msu.edu (105 IM Sport Circle, Department of Kinesiology, East Lansing, MI 48824).

If you have any questions about your role and rights as a research participant, or would like to register a complaint about this study, you may contact, anonymously if you wish, the Director of MSU's Human Research Protection Programs, Dr. Peter Vasilenko, at 517-355-2180, FAX 517-432-4503, or e-mail irb@msu.edu, or regular mail at: 202 Olds Hall, MSU, East Lansing, MI 48824.

9. DOCUMENTATION OF INFORMED CONSENT.

Your signature below indicates your voluntary agreement to participate in this study.

I, ____________________________ have read and agree to participate in this study as described above.
(Please Print Your Name)

____________________________   _____/_____/_____
(Please Sign Your Name)   *(Date)*

References

Andersen, T. E., Arnason, A., Engebretsen, L., & Bahr, R. (2004). Mechanisms of head injuries in elite football. *British Journal of Sports Medicine, 38*, 690-696.

Aubry, M., Cantu, R., Dvorak, J., Graf-Baumann, T., Johnston, K., Kelly, J., et al. (2002). Summary and agreement statement of the first international conference on concussion in sport, vienna 2001. *British Journal of Sports Medicine, 36*, 6-10.

Autti, T., Spila, L., Autti, H., & Salonen, O. (1997). Brain lesions in players of contact sports. *Lancet, 349*, 1144.

Bailes, J. E., & Cantu, R. C. (2001). Head injury in athletes. *Neurosurgery, 48*(1), 26-46.

Barnes, B. C., Cooper, L., Kirkendall, D. T., McDermott, T. P., Jordan, B. D., & Garrett, W. E. (1998). Concussion history in elite male and female soccer players. *American Journal of Sports Medicine, 26*(3), 433-438.

Besenski, N. (2002). Traumatic injuries: Imaging of head injuries. *European Radiology, 12*, 1237–1252.

Boden, B. P., Kirkendall, D. T., & Garrett, W. E. (1998). Concussion incidence in elite collete soccer players. *American Journal of Sports Medicine, 26*(2), 238-241.

Broglio, S. P., & Guskiewicz, K. M. (2001). Soccer heading: Are there risks involved? *Athletic Therapy Today, 6*(1), 28-32.

Broglio, S. P., Guskiewicz, K. M., Sell, T. C., & Lephart, S. M. (2004). No acute changes in postural control after soccer heading. *British Journal of Sports Medicine, 38*, 561-567.

Broglio, S. P., Ju, Y. Y., Broglio, M. D., & Sell, T. C. (2003). The efficacy of soccer headgear. *Journal of Athletic Training, 38*(3), 220-224.

Cantu, R. C. (2001). Posttraumatic retrograde and anterograde amnesia: Pathophysiology and implications in grading and safe return to play. *Journal of Athletic Training, 36*(3), 244-148.

Collins M., Grindell S., Lovell M., et al (1999). Relationship between concussion and neurocognitive performance in college football players. *JAMA, 282(10),* 964-970.

Committee on Head Injury Nomenclature of the Congress of Neurological Surgeons. (1966). Glossary of head injury, including some definitions of injury to the cervical spine. *Clinical Neurosurgery, 12*, 386-394.

Delaney, J.S., Al-Kashmiri, A., Drummond, R. & Correa, J.A. (2008). The effect of protective headgear on head injuries and concussions in adolescent football (soccer) players. *British Journal of Sports Medicine, 42(2),* 110-115.

Dvorak, J., & Junge, A. (2000). Football injuries and physical symptoms: A review of literature. *American Journal of Sports Medicine, 28*(suppl 5), S3-S9.

Eaton, L. (2002). Coroner cites football as reason for brain injury. *British Medical Journal, 325*, 1133.

Full90 Performance Headguards. (2007). Retrieved July 29, 2007, from http://www.full90.com/showcase/faq.asp

Gessel, L.M., Fields, S.K., Collins, C.L., Dick, R.W. & Comstock, R.D. (2007). Concussions among United States high school and collegiate athletes. *Journal of Athletic Training. 42(4),* 495-503.

Giza, C. C., & Hovda, D. A. (2001). The neurometabolic cascade of concussion. *Journal of Athletic Training, 36*(3), 228-235.

Guskiewicz, K. M., Bruce, S. L., Cantu, R. C., Ferrara, M. S., Kelly, J. P., McCrea, M., et al. (2004). National athletic trainers association position statement: Management of sport-related concussion. *Journal of Athletic Training, 39*(3), 280-297.

Guskiewicz, K. M., Marshall, S. W., Bailes, J., McCrea, M., Cantu, R. C., Randolph, C., et al. (2005). Associtation between recurrent concussion and late-life cognitive impairment in retired professional football players. *Neurosurgery, 57*(4), 719-726.

Guskiewicz, K., Weaver, N., Padua, D. & Garrett W.E. (2000). Epidemiology of concussion in collegiate and high school football players. *American Journal of Sport Medicine, 28*, 643-650.

Haywood, K. M., & Getchell, N. (2005). *Life span motor development* (Fourth Edition ed.). Champaign, IL: Human Kinetics.

Iverson, G.L., Gaetz, M., Lovell, M.R. & Collins, M.W. (2004). Cumulative effects of concussion in amateur athletes. *Brain Injury, 18(5),* 433-443.

Kirkendall, D. T., & Garrett, W. E. (2001). Heading in soccer: Integral skill or grounds for cognitive dysfunction? *Journal of Athletic Training, 36*(3), 328-333.

Kirkendall, D. T., Jordan, S. E., & Garrett, W. E. (2001). Heading and head injuries in soccer. *Sports Med, 31*(5), 369-386.

Kolb, B., & Whishaw, I. Q. (2003). *Fundamentals of human neuropsychology* (Fifth Edition ed.). New York, NY: Worth Publishers.

Lovell, M. R., Collins, M. W., Iverson, G. L., Field, M., Maroon, J. C., Cantu, R., et al. (2003). Recovery from mild concussion in high school athletes. *Journal of Neurosurgery, 98*, 295-301.

Maroon, J. C., Lovell, M. R., Norwig, J., Podell, K., Powell, J. W., & Hartl, R. (2000). Cerebral concussion in athletes: Evaluation and neuropsychological testing. *Neurosurgery, 47*(3), 659-672.

Matser, J. T., Kessels, A. G., Jordan, B. D., Lezak, M. D., & Troost, J. (1998). Chronic traumatic brain injury in professional soccer players. *Neurology, 51*(3), 791-796.

Matser, J. T., Kessels, A. G., Lezak, M. D., Jordan, B. D., & Troost, J. (1999). Neuropsychological impairment in amateur soccer players. *Journal of the American Medical Association, 282*(10), 971-973.

Matser, J. T., Kessels, A. G., Lezak, M. D., & Troost, J. (2001). A dose-response relation of headers and concussions with cognitive impairment in professional soccer players. *Journal of Clinical and Experimental Neuropsychology, 23*(6), 770-774.

McCrory, P., Collie, A., Anderson, V., & Davis, G. (2004). Can we manage sport related concussion in children the same as in adults? *British Journal of Sports Medicine, 38*, 516-519.

McCrory, P., Johnston, K., Meeuwisse, W., Aubry, M., Cantu, R., Dvorak, J., et al. (2005). Summary and agreement statement of the 2nd annual international conference on concussion in sport, prague 2004. *British Journal of Sports Medicine, 39*(Suppl I), i78-i86.

McCrory, P. R. (2003). Brain injury and heading in soccer. *British Medical Journal, 327*, 351-352.

Mueller, N.G., Machado, L., & Knight, R.T. (2002). Contributions of subregions of the prefrontal cortex to working memory: Evidence from brain lesions in humans. *Journal of Cognitive Neuroscience, 14(5)*, 673-686.

Pickett, W., Streight, K., Simpson, K., & Brison, R. J. (2005). Head injuries in youth soccer players presenting to the emergency department. *British Journal of Sports Medicine, 39*, 226-231.

Putukian, M., Echemendia, R.J., & Mackin, S. (2000). The acute neuropsychological effects of heading in soccer: a pilot study. *Clinical Journal of Sports Medicine, 10(2)*, 104-109.

Rabadi, M. H., & Jordan, B. D. (2001). The cumulative effect of repetitive concussion in sports. *Clinical Journal of Sports Medicine, 11*, 194-198.

Rutherford, A., Stephens, R., & Potter, D. (2003). The neuropsychology of heading and head trauma in association football (soccer): A review. *Neuropsychology Review, 13*(3), 153-179.

Saladin, K. (2001). *Anatomy and physiology: The unity of form and function*. New York: McGraw-Hill.

Schatz, P., Pardini, J. E., Lovell, M. R., Collins, M. W., & Podell, K. (2006). Sensitivity and specificity of the ImPACT test battery for concussion in athletes. *Archives of Clinical Neuropsychology, 21*(1), 91-99.

Smodlaka, V. J. (1984). Medical aspects of heading the ball in soccer. *Physician and Sports Medicine, 12*, 127-131.

Sterr, A., Herron, K., Hayward, C., & Montaldi, D. (2006). Are mild head injuries as mild as we think? neurobehavioral concomitants of chronic post-concussion syndrome. *BMC Neurology, 6*(7)

Thurman, D. J., Branche, C. M., & Sniezek, J. E. (1998). The epidemiology of sports related traumatic brain injuries in the united states: Recent developments. *Journal of Head Trauma Rehabilitation, 13*(2), 1-8.

Tysvaer, A. T., & Storli. (1989). Soccer injuries to the brain. A neurologic and electroencephalographic study of active football players. *American Journal of Sports Medicine, 17*(4), 573-578.

Tysvaer, A. T., & Storli, O. (1981). Association football injuries to the brain. *British Journal of Sports Medicine, 15*, 163-166.

Van Kampen, D. A., Lovell, M. R., Pardini, J. E., Collins, M. W., & Fu, F. H. (2006). The "value added" on neurocognitive testing after sports-related concussion. *American Journal of Sports Medicine, 34*, 1630-1635.

Webbe, F.M., & Ochs, S.R. (2003). Recency and frequency of soccer heading interact to decrease neurocognitive performance. *Applied Neuropsychology, 10(1)*, 31-41.

Withnall, C., Shewchenko, N., Wonnacott, M., & Dvorak, J. (2005). Effectiveness of headgear in football. *British Journal of Sports Medicine, 39*(Suppl I), i40-i48.

Zemper E. (2003). Two-year prospective study of relative risk of a second cerebral concussion. *American Journal of Physical Medicine and Rehabilitation, 82*, 653-659.