

**AN EXAMINATION OF THE CUMULATIVE EFFECTS OF HEADING ON
NEUROCOGNITIVE FUNCTIONING IN MALE COLLEGIATE SOCCER
ATHLETES**

by

Jenifer Halterman, ATC

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Jenifer Halterman

Approved: _____
Thomas W. Kaminski, Ph.D., ATC, FNATA, FACSM
Professor in charge of thesis on behalf of the Advisory Committee

Approved: _____
Todd D. Royer, Ph.D.
Chair of the Department of Kinesiology and Applied Physiology

Approved: _____
Kathleen S. Matt, Ph.D.
Dean of the College of Health Sciences

Approved: _____
Charles G. Riordan, Ph.D.
Vice Provost for Graduate and Professional Education

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ABSTRACT

Soccer is the most popular team sport in the world. Heading a soccer ball is an inherent and strategic part of the sport, and it has the potential to result in concussion if performed incorrectly. It is important to determine if each episode of heading results in minor insults to the brain and if there are cumulative effects resulting in impaired neurocognitive functioning. **PURPOSE:** This study examined the relationship between heading exposure, field position, and scores of neuropsychological test performance over the course of a collegiate playing career. **METHODS:** The database consists of collegiate male soccer athletes who have completed a pre-participation Immediate Post-Concussion Assessment and Cognitive Testing (ImPACT) battery. The number of headers and header type (pass, shot, clear, unintentional deflection) were tracked for each player over the course of the playing career. At the conclusion of each season, the ImPACT battery was completed again. **RESULTS:** None of the correlation coefficients calculated between the three predictors of heading and the ImPACT composite scores following the third season of soccer were statistically significant. **CONCLUSIONS:** No relationship exists between purposeful heading and measures of neuropsychological test performance in male collegiate soccer players. Additionally, there was no effect of field position on the level of cognitive functioning of the soccer athletes.

Chapter 1

INTRODUCTION

Soccer is the most popular team sport in the world, and it is the fastest-growing team sport in the United States. Worldwide, there are nearly 200 million players (Boden, Kirkendall, & Gerrett, 1998; Broglio, Guskiewicz, Sell, & Lephart, 2004). With 200 million participants and purposeful heading of a soccer ball being an important part of the game, it is imperative to determine if heading is detrimental to the cognitive function of soccer players, especially those who experience chronic exposure to heading. Heading is uniquely utilized in the game of soccer with the purpose of maneuvering the ball in order to clear it from the defensive end, to maintain possession, or to score a goal.

Neuropsychological testing has emerged as a means to accurately and objectively assess the scope of neurocognitive function. The various tests are able to provide data about the “speed of information processing, reaction time, attention and concentration, scanning and visual tracking ability, memory recall, and problem-solving abilities” (Putukian, Echemendia, & Mackin, 2000). The sensitivity (Schatz, Pardini, Lovell, Collins, & Podell, 2006) of these tests allows for the recognition of cognitive dysfunction (Kaminski, Cousino, & Glutting, 2008).

Sport-related concussions are prevalent in the sport of soccer (Boden et al., 1998 & Comstock, Collins, & McIlvain, 2010) and are of concern to the sports health care professional. Evidence from combative sports along with American football has suggested that repeated blows to the head are not always benign

(Naunheim, Standeven, Richter, & Lewis, 2000). Head impacts sustained during American football and boxing have been measured to produce accelerations between 150 and 450 G and 100 G, respectively, with contact time lasting 200 to 250 msec for American Football and 14 to 18 msec for boxing (Levendusky et al., 1988; Armstrong et al., 1988). Forces of 600 N have been measured in boxing impacts (Kirkendall et al., 2001). Two early studies reported the force of a soccer ball traveling at 65 km/h to be between 850 to 912 N with an acceleration of 30 to 55 G (gravitational forces). The contact time between the ball and the head was calculated to last about 10.23 msec (Levendusky et al., 1988; Armstrong et al., 1988). Repetitive insults to the head during purposeful heading as part of the sport of soccer need to be examined further. Although previous research has indicated no deleterious effects of acute bouts or one season of soccer heading (Putukian et al. 2000 & Kaminski et al. 2008), no research exists examining the frequency of headers during practices and games over an athlete's playing career and the effect on neurocognitive functioning. Therefore, the purpose of this study was two-fold: to identify if there is a relationship between purposeful heading and measures of neuropsychological test performance in male collegiate soccer players and to identify if there is a difference between the total number of headers and measures of neuropsychological test performance between male soccer players of different field positions (offense/midfield and defense). The penalty box and the midfield line are the two primary areas on the soccer field where head injuries occur because these are the areas where the players are intensely competing for the ball (Kirkendall et al., 2001; Rutherford et al. 2003). Therefore, we hypothesize that a defensive player will head the ball more frequently and forcefully

due to the general location of the defensive player and his role in assisting with protection of the goal.

Chapter 2

METHODS

2.1 Participants

Data from a total of 16 Division I male soccer players were extracted from a larger database that tracks these players at the University of Delaware. All subjects provided written consent (UDIRB HS09-110) prior to the initiation of testing (Appendix 1). A team physician cleared all athletes for participation following a thorough pre-participation physical examination. An athlete who sustained a concussion at any point during the study had his data excluded from the study.

2.2 Procedures

Each soccer player completed a computerized test of the Immediate Post-Concussion Assessment and Cognitive Testing (ImPACT) prior to the start of his first season as part of the routine pre-participation physical examination for intercollegiate soccer athletes at the University of Delaware. These scores served as baseline comparison measures for any subsequent tests administered following a concussion. The test was administered to the players in a quiet environment.

The ImPACT instrument is a computer-based program used to assess neurocognitive function and concussion symptoms. It consists of three main parts: demographic data, neuropsychological tests, and the Post-Concussion Symptom Scale (PCSS). The software program consists of six neurocognitive test modules that evaluate different aspects of cognitive functioning. The Word Memory and the

Design Memory test modules assess immediate and delayed memory for words and designs, respectively. Attention, concentration, and working memory are both measured by the X's and O's and the Three Letters test modules. X's and O's also measure reaction time, whereas Three Letters measures visual-motor speed. Visual processing speed, learning, and memory are assessed through the Symbol Match test module. The Color Match test module serves as a measure of focused attention, response inhibition, and reaction time. Five composite scores (verbal memory, visual memory, reaction time, processing speed, and impulse control) are calculated based on combinations of various aspects of these six test modules. The ImPACT test has been shown to be a valid and reliable measure of neurocognitive function and useful in assessing changes post-concussion (Iverson et al., 2002; Iverson, Lovell, & Collins, 2003).

At each soccer practice and game, the number and type of headers (shot, pass, clear, unintentional/deflection) were recorded for each player by the certified athletic trainer or the athletic training students assigned to work with the team (Appendix 2). The headers were also tallied during the spring season, but only during games. These headers were added to the previous fall season's game headers. Upon completion of each season, the headers were totaled and entered into the database. Within seven days following the conclusion of the competitive (fall) season, all soccer players returned for post-season neuropsychological testing. The ImPACT test was administered in the same manner as described above.

2.3 Data Analysis

Two methods were employed to analyze results from the current study. The first method employed bivariate correlation coefficients calculated between the

three predictors of total practice headers, total game headers, and total practice and game headers combined obtained over 3 seasons for each player and the ImPACT composite scores (verbal memory, visual memory, visual motor speed, reaction time, impulse control, and total symptom score) following each athlete's third season of soccer. Two groups were formed for the second set of analyses: offense/midfielder versus defense. The dependent variables were the ImPACT composite scores: verbal memory, visual memory, visual motor speed, reaction time, impulse control, and total symptom score. All six dependent variables were measured on the interval scale. Therefore, independent samples t-tests were utilized during the second set of analyses.

Chapter 3

RESULTS

Table 1 presents the demographics of the 16 subjects included in this study. The average height for the subjects was 176.2 ± 5.4 cm and the average mass was 69.3 ± 5.3 kg. 11 of the subjects were offense/midfielders and 5 were defenders. The average heights and weights according to these two positions are listed in Table 2. The average total headers according to type and situation are listed in Table 3. Table 4 lists the means and standard deviations for all predictors and criteria.

Table 5 presents means and standard deviations for the predictors and criteria used to calculate correlation coefficients. The bivariate correlations themselves are presented in Table 6. Results show that none of the 18 correlation coefficients is statistically significant. The lack of statistical significance came as no surprise because the sample size of 16 is quite small. A post hoc power analysis was completed for the sample size of 16. It assumed a two-tailed significance level of $p = .05$ and a medium effect size (Cohen's 1988, $r = .30$). Results showed power = .21, meaning that there was only a 21 percent chance of reaching statistical significance with the current sample. Therefore, the current study is underpowered.

At the same time, it is important to recognize that effect sizes were all small to medium for the obtained correlation coefficients. Cohen (1988) established guidelines for interpreting the magnitude of correlation coefficients, where an $r < .10$ represents a small effect size; an $r = .30$ represents a medium effect size; and an $r > .50$ represents a large effect size. Regardless of the area of study, investigations that report

successful outcomes show medium effect sizes or larger (Coe, 2002; Cohen 1988; Lipsey & Wilson, 2001; Rosnow & Rosenthal, 2003). In the current investigation, 39 percent of the correlations showed negligible-to-small effect sizes (7 out of 18); and, all of the correlations were less than the .30 criterion for a medium effect size. Therefore, it is reasonable to infer that relationships between the number of headers and the neuropsychological outcome measures were either negligible or small.

Table 7 presents means and standard deviations for the six neuropsychological variables, and it does so separately for the two position groups of offense/midfield and defense. Results across the six independent-samples t-tests were uniform. The analysis closest to reaching statistical significance took place on the ps3imcont comparison ($t = 1.297$, $df [14]$, $p = .20$).

Table 1 Demographics of included subjects

Subject	Position	Height (cm)	Mass (kg)	Prev concussion
00001	Defense	185.4	79.5	1
00002	Offense/midfield	177.8	66.8	0
00003	Offense/midfield	172.7	63.6	0
00004	Defense	180.3	75.5	1
00005	Offense/midfield	167.6	70.5	0
00006	Defense	175.3	76.4	0
00007	Offense/midfield	175.3	65.9	0
00008	Offense/midfield	172.7	65.9	0
00009	Offense/midfield	172.7	61.4	0
00010	Offense/midfield	175.3	70.5	0
00012	Offense/midfield	182.9	69.1	1
00013	Offense/midfield	185.4	77.3	0
00014	Offense/midfield	170.2	68.2	0
00015	Defense	175.3	68.2	0
00034	Defense	170.2	65.9	0
00035	Offense/midfield	180.3	63.6	0
		Average height = 176.2 ± 5.4	Average mass = 69.3 ± 5.3	

Table 2 Average height and mass by position

Position	Height (cm)	Mass (kg)
Offense/midfield	175.7 ± 5.4	67.5 ± 4.3
Defense	177.3 ± 5.8	73.1 ± 5.8

Table 3 Average total headers according to type and situation

	Mean	Standard Deviation
Total Practice Clears	20.1	10.7
Total Practice Passes	85.4	22.3
Total Practice Shots	16.4	12.9
Total Practice Deflections	5.3	4.2
Total Game Clears	54.3	37.9
Total Game Passes	69.8	30.9
Total Game Shots	4.7	9.1
Total Game Deflections	9.2	6.2

Table 4 Means and standard deviations for all predictors and criteria

Variable	Mean	Standard Deviation
Total practice headers	127.2	28.8
Total game headers	138.3	63.0
Total headers	265.5	80.0
Total headers- DEFENSE	252.2	81.3
Total headers- OFFENSE/MIDFIELD	271.5	82.7

Table 5 Means and standard deviations for measures used to calculate bivariate correlations

Variable	Mean	Standard Deviation
Totheadpx	127.2	28.8
Totheadg	138.3	63.0
Totalheads	265.5	80.0
Ps3imcont	8.23	8.1
Ps3memverb	88.7	7.0
Ps3memvis	82.1	10.8
Ps3rxntime	0.6	0.1
Ps3tss	2.4	7.4
Ps3vismotsp	39.0	9.3

N = 16

(Totheadpx = total practice headers; Totheadg = total game headers; Totalheads = total practice and game headers; Ps3imcont = post-season 3 impulse control; Ps3memverb = post-season 3 verbal memory; Ps3memvis = post-season 3 visual memory; Ps3rxntime = post-season 3 reaction time; Ps3tss = post-season 3 total symptom score; Ps3vismotsp = post-season 3 visual motor speed)

Table 6 Bivariate correlations between predictors over 3 seasons and outcomes after the third season

	Predictors		
	Toheadpx	Toheadg	Totalheads
Ps3memverb	.083	.301	.267
Ps3memvis	.280	-.023	.083
Ps3vismotsp	-.291	.093	-.032
Ps3rxntime	.030	-.176	-.128
Ps3imcont	-.189	-.224	-.245
Ps3tss	.168	.122	-.036

Notes: N = 16; none of the correlation coefficients was statistically significant at $p = .05$

(Ps3memverb = post-season 3 verbal memory; Ps3memvis = post-season 3 visual memory; Ps3vismotsp = post-season 3 visual motor speed; Ps3rxntime = post-season 3 reaction time; Ps3imcont = post-season 3 impulse control; Ps3tss = post-season 3 total symptom score)

Table 7 Means (SD) for the neuropsychological measures by position

	Position	
	Defense	Offense/midfield
Ps3memverb	91.2 (4.4)	87.6 (7.8)
Ps3memvis	85.4 (7.0)	80.6 (12.2)
Ps3vismotsp	38.4 (8.1)	39.3 (10.2)
Ps3rxntime	0.6 (.07)	0.6 (.11)
Ps3imcont	4.4 (3.0)	10.0 (2.8)
Ps3tss	0.2 (0.45)	3.5 (8.9)

Note: $n = 5$ for the Defense group and $n = 11$ for the Offense/midfield group
(Ps3memverb = post-season 3 verbal memory; Ps3memvis = post-season 3 visual memory; Ps3vismotsp = post-season 3 visual motor speed; Ps3rxntime = post-season 3 reaction time; Ps3imcont = post-season 3 impulse control; Ps3tss = post-season 3 total symptom score)

Chapter 4

DISCUSSION

The main finding of this study was that no relationship existed between purposeful heading and measures of neuropsychological test performance in male collegiate soccer players. Although there was a limited sample size in this study, these results appear to be consistent with current literature examining the effects of soccer heading on cognitive functioning (Kaminski et al., 2008; Bucks, Kaminski, Glutting, Collina, & Webner 2009). This study examined the effect of total practice headers, total game headers, and total practice and game headers combined for 3 seasons of collegiate soccer. No relationship was observed between these three predictors and neuropsychological performance as measured by the ImPACT battery.

This study also sought to determine if there was a difference between the total number of headers and neuropsychological test performance according to field position. Although it was hypothesized that the defenders would exhibit a decrease in cognitive functioning related to an increase in headers as compared to the offense/midfield position, this effect was not observed in the small set of subjects included in this study. Interestingly, the defenders headed the ball slightly less on average than the offense/midfield position.

Because heading the ball is such an integral aspect of the game of soccer, it is imperative to determine if purposeful heading can negatively affect cognitive functioning. The number of total game headers over the course of a playing career has been estimated to be about 2000 in about 300 top-level games. Because this figure did

not account for headers accumulated during practices, the estimated total number of lifetime headers is probably much greater than 2000 (Tysvaer and Storli, 1981). In our study, the total number of headers over 3 years ranged from 130 to 422 headers in 138 to 198 exposures (practices and games combined). Furthermore, ball to head impacts in soccer have been compared to head impacts sustained during boxing. A soccer ball traveling at 65 km/h produces forces between 850 to 912 N, whereas forces of 600 N have been observed in boxing impacts (Levendusky et al., 1988; Armstrong et al., 1988; Kirkendall, Jordan, & Garrett, 2001). Repetitive blows to the head during a boxing match have been shown to result in declines in neurocognitive test performance (Ravdin, Barr, Jordan, Lathan, & Relkin, 2003). With data such as this, including results of earlier research (Master et al., 1999; Witol & Webbe, 2003), it is understandable that purposeful soccer heading has been linked to decreases in cognitive functioning. Despite this premise, data from the current study did not demonstrate deficits in cognitive functioning related to purposeful soccer heading.

Methodological flaws and limitations in some of the current research limit the conclusions that can be drawn about the effects of heading on cognition. In a study that found mild-to-severe deficits in professional soccer players as compared to controls, a baseline test was not given (Tysvaer & Lochen, 1991). Without the baseline examination, there is no means of comparison within each of the athletes prior to and following participation. Therefore, it cannot be concluded that the deficits were a result of soccer participation because they may have been present before participation. Another flaw in current research is the lack of control for previous concussion. Matser et al. concluded that cognitive deficits occurred as a result of participation in amateur soccer (Matser et al., 1999). However, because many of the

subjects included in this study had sustained a previous concussion, it cannot be determined if soccer participation or history of concussion was the causative factor for the observed decline in neurocognitive functioning. Another limitation is the use of a history of heading questionnaire to assess the frequency of headers for each athlete. This method is inaccurate because it relies on the athlete's honesty and memory and may be subject to recall bias (Coughlin, 1990).

The current study employed a header tally sheet to record the headers as they occurred at each practice and game over the 3 seasons in which the athletes participated. Additionally, a baseline neuropsychological test was administered before the start of each player's first season. If a subject suffered a concussion during a season, his data were not included for that year because concussions have been shown to result in an increased vulnerability to further head impacts and may have skewed the results (Guskiewicz, Weaver, Padua, & Garrett, 2000). None of the subjects included in this study sustained a concussion during any of the seasons in which he participated. It is important to note that the data set would have been larger, but some subjects were excluded due to sustaining a concussion and only had complete data for one or two seasons.

Although there seems to be some evidence supporting the idea that soccer heading is detrimental to neurocognitive functioning (Master et al., 1999; Witol & Webbe, 2003), this study did not produce such findings. The current findings are physiologically supported in a study by Zetterberg et al. that measured levels of biochemical markers in the cerebrospinal fluid (CSF) known to be associated with neuronal injury. Two CSF biomarkers are proteins associated with axonal injury and two are associated with glial cell injury. Increases in the levels of these proteins have

been observed following a stroke as well as in amateur boxers. These four proteins have been accepted as “sensitive and specific indicators of damage to the brain” (Zetterberg et al.,2007). Two groups of amateur soccer players headed a soccer ball 10 and 20 times, respectively. 7-10 days following the bout of heading, CSF was analyzed for the four proteins associated with neuronal damage. CSF was also collected and analyzed for 10 healthy, matched controls. No significant differences were found between the biomarker concentrations among any of the groups. This study by Zetterberg and colleagues suggests that acute, purposeful heading of the soccer ball does not result in neuronal injury. Despite the fact that our study did not utilize the biomarkers suggested by Zetterberg and colleagues, we speculate that there was no neurocognitive deficits noted in the 16 subjects we prospectively tracked.

A limitation of the current study is the small sample size. With only 16 subjects, the study was underpowered. Additionally, the purpose of the study was to examine the effects of heading over the athlete’s collegiate playing career. A large number of players quit the team after only one or two years of participation; therefore, the data set was much smaller than what was expected for 8 years worth of data collection. A baseline neuropsychological test was administered before each athlete’s participation at the university to serve as the comparison for the third year post-season test. Although one might argue that cognitive deficits as a result of soccer heading may have already resulted in a decreased score before the athletes reach the collegiate level of competition, our median values for verbal memory, visual memory, processing speed, and reaction time fell within the “average” classification range when compared to a large normative database published by Iverson and colleagues (Iverson et al., 2003). We can not make an assumption on impulse control category because

there is no normative data at this time. In addition, neuropsychological testing is designed to detect deficits following concussion, but it has not been fully validated as an accurate means of detecting the minor changes that may result from soccer heading. Ideally, future studies should utilize the header tracking form to accurately assess the frequency of headers at all practices and games beginning as close to the beginning of a young child's soccer participation. A baseline neurocognitive test should be administered immediately and the headers of these young players should be tracked for years to accurately assess the true effect of a lifetime of soccer heading on neurocognitive functioning.

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Appendix A
INFORMED CONSENT

**University of Delaware Human Subjects
Informed Consent Form**

Project Title: “Examination of Purposeful Heading and Neuropsychological Test Performance in Intercollegiate Soccer Players”

Investigator: Thomas W. Kaminski, PhD, ATC, University of Delaware

Please read this consent agreement carefully before you decide to participate in this study.

Purpose of the research study:

This study is examining the usefulness of neuropsychological testing in the evaluation and management of concussion in a student-athlete population. Because you are a student-athlete and “at risk” for concussion during participation in soccer, you are being asked to participate in this research study. Your teammates and counterparts from the other soccer team here at UD are also participating.

What you will do in the study:

- 1.) As part of the UD medical examination process, you are required to complete the ImPACT neuropsychological test program. The ImPACT (Immediate Post-Concussion Assessment and Cognitive Testing) computerized test program consists of three parts and includes: (1) sports and health history, (2) current symptoms and conditions, and (3) neurocognitive testing [eight modules]. The neurocognitive test domains measured include memory, processing speed, motor functioning, executive functioning, and attention. The entire test is normally completed in 25 minutes. Data derived from the ImPACT test will be used in this study.
- 2.) If you experience a blow to the head or body during the course of the soccer season that results in confusion, disorientation, memory disturbance, or loss of consciousness, **we ask that you report the incident immediately to your coach, athletic trainer, and/or physician.**
- 3.) Within 24 hours after you report this incident, you will be administered the same battery of ImPACT tests that you received during the baseline evaluation and described above.
- 4.) The same tests will then be administered on day three, five, and seven following the concussion and again at the end of the season.
- 5.) Performance on these tests *may* affect your participation in soccer. The results of your performance on the computerized battery of tests will be kept strictly confidential, but if deficits in performance from baseline are evident following a concussion, the results of the test will be shared with the UD athletics medical staff. However, return-to-play decisions will rest solely upon the discretion of the team’s athletic trainer, coach, and/or physician.

- 6.) If you *do not* suffer from a concussion during the season you will be asked to participate in another ImPACT test session at the end of the season.
- 7.) Throughout the season at both practices and matches a designated member of the athletic training staff will be tracking any purposeful headers that you perform as part of playing soccer. The heading data will eventually be compared with your ImPACT data.

Time required:

Two test sessions requiring 30 minutes each. Athletes suffering in-season concussions will require more than two test sessions that will be scheduled on an individual basis.

Risks:

There are no known physical risks in completing the computerized tests. The tests do require active attention, concentration, and mental effort and may result in mental frustration, particularly when completed during a post-concussion state. If severe mental frustration is apparent, testing will be discontinued.

Benefits/Compensations:

There are no direct benefits to you for participating.

Confidentiality:

Data will be kept confidential, however in cases of concussion, follow-up test results *may* be shared with the UD athletics medical staff. Your information will be assigned a code number. The list connecting your name to this number will be kept in a locked file. When the study is completed and the data have been analyzed, the list will be destroyed. Your name will not be used in any report.

Voluntary Participation:

Your participation in the study is completely voluntary. There is no penalty for not participating.

Right to withdraw from the study:

You have the right to withdraw from the study at any time without penalty.

Payment:

You will receive no payment for participating in the study.

Who to contact if you have questions about the study:

Dr. Thomas W. Kaminski, Associate Professor, University of Delaware, 302-831-6402 or kaminski@udel.edu

Who to Contact About Your Rights in the Study:

If you have questions regarding the rights of individuals who agree to participate in this research, you may call Chair of the Human Subjects Review Board, (302) 831-4007 University of Delaware Research & Graduate Studies office.

Agreement:

I have read the procedure described above. I voluntarily agree to participate in the procedure and I have received a copy of this description.

Participant: _____

Date: _____

Principal Investigator: _____

Date: _____

Appendix B
HEADER TRACKING FORM

Appendix C
SPECIFIC AIMS

Specific Aims

Soccer is the most popular team sport in the world, and it is the fastest-growing team sport in the United States. Worldwide, there are nearly 200 million players (Boden et al., 1998; Broglio et al., 2004). With 200 million participants and purposeful heading of a soccer ball being an important part of the game, it is imperative to determine if heading is detrimental to the cognitive function of soccer players. Heading is uniquely utilized in the game of soccer with the purpose of maneuvering the ball in order to clear it from the defensive end, to maintain possession, or to score a goal. Although heading is an intuitive part of the game, a proper technique should be employed to minimize the risk of injury.

Due to the nature of soccer, the risk of sustaining an injury to the head and face is relatively high. Common injuries are abrasions, minor lacerations, contusions, skull fractures, and concussions. The mechanism that most often results in a head injury is the accidental contact of the head with an object other than the ball when attempting to head the ball. This often results in cerebral concussion, which results in neurocognitive impairment for a period following injury. In addition to concussion, multiple sub-concussive impacts to the head may also result in cognitive dysfunction (Queen, Weinhold, Kirkendall, & Yu, 2003). A decline in neurocognitive test performance is observed as repetitive blows to the head are accumulated during a boxing match (Ravdin et al., 2003). It should be noted, however, that boxing blows usually involve linear and rotational forces on the skull whereas soccer generally involves only linear forces.

Neuropsychological testing has emerged as a means to accurately and objectively assess the extensive scope of neurocognitive function.

Neuropsychological testing provides data about the “speed of information processing, reaction time, attention and concentration, scanning and visual tracking ability, memory recall, and problem-solving abilities” (Putukian et al., 2000). The high sensitivity of these tests allows for the recognition of cognitive dysfunction (Kaminski et al. 2008).

Neurocognitive impairment as a result of the cumulative effects of heading is a concern due to the nature of heading in the sport of soccer. The current research has not been able to support or refute this matter. The results of a study by Putukian, Echemendia, and Mackin showed “that there were no significant effects of heading on cognitive function during one session for men and women collegiate soccer players”(Putukian et al., 2000). However, this study is limited due to the use of a small sample size and because the performance took place during a practice session. The intensity and effort during the heading drills may have been lower during the practice session than if the study had used heading data collected during an actual competition. In a study by Guskiewicz et al., “soccer athletes did not demonstrate impaired neurocognitive function when compared with the non-soccer athletes or student non-athletes” (Guskiewicz, Marshall, Broglio, Cantu, & Kirkendall, 2002). This study relied on a history of heading questionnaire to determine the frequency of heading during a player’s soccer career. This is an unreliable method of determining frequency of heading because it relies solely on the athlete’s memory and honesty. These studies only observe the acute effects of heading on neurocognitive levels. So although these studies have found no neurocognitive decrease as a result of acute soccer heading, no research exists using a header tracking form to record the frequency of headers during practices and games over an athlete’s playing career.

Therefore, the purpose of this study is to determine if there are long-term effects of heading over a male soccer player's playing career.

Specific Aim 1: To identify if there is a relationship between purposeful heading and measures of neuropsychological test performance in male collegiate soccer players.

Hypothesis 1.1: There will be no relationship between the total number of headers and neuropsychological test performance as measured by the ImPACT battery. Recent studies have found no evidence of a detrimental relationship between purposeful soccer heading and cognitive functioning as measured by performance on neuropsychological tests (Kaminski et al., 2008; Bucks et al., 2009).

Specific Aim 2: To identify if there is a difference between the total number of headers and measures of neuropsychological test performance between male soccer players of different field positions (offense/midfield and defense).

Hypothesis 2.1: There will be a relationship between total headers and neuropsychological test performance in the defenders as compared to the other field position; as the number of headers increases there will be a decrease in the scores on the neuropsychological test. The penalty box and the midfield line are the two primary areas on the soccer field where head injuries occur because these are the areas where the players are intensely competing for the ball (Kirkendall et al., 2001; Rutherford et al. 2003). Therefore, we hypothesize that a defensive player will head the ball more frequently and forcefully due to the general location of the defensive player and his role in assisting with protection of the goal.

Appendix D

BACKGROUND AND SIGNIFICANCE

Background and Significance

Soccer can be considered one of the most popular sports in the world and the number of participants is increasing steadily. Due to the nature of the sport, running, cutting, and jumping are all integral parts of the game. As such, many injuries occur when these techniques are improperly executed. Furthermore, although direct physical contact in the sport of soccer is technically prohibited, many injuries occur as a result of contact between players. Due to the widespread popularity of soccer and increasing number of players, it is important to understand the type, method, rate of occurrence, and severity of the most common soccer injuries to aid in the prevention and rehabilitation of these injuries. In a 2008 study by Azubuike and Okojie, an 81.6% injury frequency rate was observed in soccer athletes ranging from amateur leagues to professional and premiership leagues. Sprains (33.3%) and strains (13.2%) were the two most common injuries. The lower extremity (ankle, knee, thigh) had the highest injury rate (Azubuike & Okojie, 2008). Although not as common, head injuries are present in soccer. During a game of soccer, the field players are not permitted to use their hands or arms to touch the ball in any way. Therefore, the rest of the body is used to control, pass, or shoot the ball. Throughout the evolution of soccer, heading has become a popular aspect of the game as a means to control, clear, or advance the ball either to another teammate or into the goal. Heading has emerged as a unique and tactical skill that has become a permanent and important staple in soccer. However, heading does not occur without injury. The High School RIOTM is an online tool that is used to study injury data in the high school athletic population. Data relating to injury type, occurrence, location, and athlete exposure are reported by certified athletic trainers on a weekly basis over the course of an entire academic year.

The 2010 High School RIO™ reports that heading results in an injury rate of 10.5% during competition and 3.9% during practice. Additionally, the data reported in 2010 demonstrates that 30% of the concussions were a result of heading the ball (Comstock, 2010). However, as highlighted below, very few of the concussions are the actual result of head and ball contact.

Purposeful Heading as a Soccer Skill

Because heading is employed as a means of gaining possession of the ball, opposing players battle for the ball competitively. Injuries can result if misjudgments or errors are made. Boden et al. (1998) prospectively observed 29 concussions in 26 Atlantic Coast Conference male and female soccer players in two consecutive seasons. The mechanisms for the concussions reported in this study from greatest occurrence to least were contact with an opposing player's head, unexpected contact with a ball that was kicked at full force from a close range, contact with the ground caused by loss of balance, contact with an opposing player's elbow, knee, or foot respectively, and finally contact with the goalpost (Boden et al., 1998). Additionally, Rabadi et al. (2001), credits the minor subconcussive strikes when heading the ball as another potential mechanism for injury to the head (Rabadi & Jordan, 2001). The maneuver of heading the ball has been observed by Naunheim et al. (2000) to produce forces up to 54.7 g, which may be high enough to cause neurologic issues. This is 160% to 180% greater than accelerations of impacts sustained during football and hockey games (Naunheim, Standeven, Richter, & Lewis, 2000). Two early studies reported the force of a soccer ball traveling at 65 km/h to be between 850 to 912 N with an acceleration of 30 to 55 G (gravitational forces). The contact time between the ball and the head was calculated to last about 10.23 msec. They compared this to the head impacts

sustained during American football and boxing that produced accelerations between 150 and 450 G and 100 G, respectively, with contact time lasting 200 to 250 msec for American Football and 14 to 18 msec for boxing (Levendusky et al., 1988; Armstrong et al., 1988). Forces of 600 N have been measured in boxing impacts (Kirkendall et al., 2001). The risk of head injury increases as the forces of impact increase and the time of impact decreases (Kirkendall et al., 2001). The impact value of a soccer ball traveling at 65 km/h was calculated by Levendusky et al. to range from 12.4 and 13.7 N/sec (Levendusky et al., 1988). This value is much lower than the proposed 22 N/sec of force that was deemed by Schneider and Zernicke (1988) to be the amount of force necessary to result in a concussion (Schneider & Zernicke, 1988). Additionally, Holbourn and Edin (1943) propose that injuries to the head are caused more frequently by rotational impacts and that higher linear impacts to the head can be absorbed with less resultant injury. Linear forces are most frequently experienced during purposeful heading of the ball (Holbourn & Edin, 1943). However, Tysvaer and Lochen (1991) speculated that the accumulation of impacts to the head below a level that results in a diagnosed concussion might result in larger declines in neurocognitive functioning than experiencing a single mild concussion (Tysvaer and Lochen, 1991). After recording the total number of headers in twenty soccer matches (ten first division game, six English games, and four international games), Tysvaer and Storli (1981) found an average of six headers per player per match, which can be translated to about 2000 headers in 300 games over the course of a playing career (Tysvaer and Storli, 1981). This study did not take into account the number of headers accumulated during the lifetime of practices, so it can be assumed that the actual number of headers is significantly greater than 2000. Therefore, it is imperative to determine the

consequences of the accumulation of such a large number of subconcussive blows to the head. Currently, it does not seem clear if there is a direct effect of heading on neurological functioning, but a study by Matser, Kessels, Lezak, Jordan, and Troost (1999), found a positive correlation between length of a soccer athlete's playing career and the risk of cognitive impairment. It is probable that an increase in the amount of headers accompanied the increase in the length of the playing career. This increase in header count may have had an effect on the development of cognitive impairment. Although the impact of one instance of purposeful heading of a soccer ball may not produce forces greater than that which results in a concussion, the accumulation of a large number of headers and thus the sum of these subconcussive forces over an athlete's entire playing career may have an effect on the neurocognitive function of these athletes.

Concussion

A concussion or mild traumatic brain injury is defined as a blow or penetrating force to the head, which leads to a disruption of normal cognitive functioning (Ragan, Herrmann, Kang, & Mack, 2009). Because about 300,000 sport-related concussions occur each year, there has been an increase in the literature on the diagnosis, treatment, and management of mild traumatic brain injuries (Ragan et al. 2009; Schatz et al., 2006). Decreased cognitive performance as a result of the cumulative effects of concussions as well as an increased chance of sustaining another concussion seems to be a common trait observed in athletes with a history of concussions (Schatz et al., 2006). In addition to these effects, sustaining multiple sport-related concussions can also cause symptoms of increased severity such as disorientation, amnesia, and loss of consciousness. Therefore, it is important that a

concussion be properly diagnosed (Schatz et al. 2006). Of equal importance is the ability to accurately assess the progress and full recovery of the concussed athlete to prevent premature return-to-play. Premature return-to-play increases the risk of sustaining a more severe brain injury. As a way of assessing the severity of the concussion sustained and the progression towards full recovery, subjective evaluations and objective neurocognitive assessments have been developed. The clinical examination, performed by a certified athletic trainer for example, remains the gold standard for sport-related concussion assessment, but information obtained from symptom reports, neurocognitive evaluations, and postural control assessments should be used to supplement these findings. Because neurocognitive evaluations have proven to be sensitive to detecting the negative effects on cognition secondary to sustaining a concussion, they should be utilized as a part of the assessment (Broglio, Macciocchi, & Ferrara, 2007). The use of self-reported symptom data is often not sufficient to determine the level of injury. Greater than 90% of sport-related concussions result in no observable loss of consciousness, minimal to no posttraumatic amnesia, and only slight disorientation (Miller, Adamson, Pink, & Sweet, 2007). Because the state of confusion and mental status changes are subtle and usually resolve within 15 minutes during a grade 1 concussion, these symptoms often go unnoticed (Kelley & Rosenberg, 1997). Therefore, it is important to include neurocognitive tests that are able to identify these changes.

Concussion Assessment: ImPACT

Lovell et al. designed the Immediate Post-Concussion Assessment and Cognitive Testing (ImPACT) in order to provide a readily accessible and standardized method of testing neuropsychological performance within athletes (Maroon et al.,

2000). The ImPACT was developed to assess various levels of cognitive functioning (attention, memory, processing speed, and reaction time) (Schatz et al., 2006). It uses a comparison of baseline test scores to post-injury test scores to determine the progression and resolution of the concussion. It was specifically designed to track recovery over the days and weeks following a sport-related concussion (Miller et al., 2007). The return of the post-injury scores to baseline levels is one factor that can be used to assist in the return-to-participation decision. By comparing post-concussion ImPACT scores to the preseason baseline scores, identification and treatment for the concussion and its associated changes in cognition becomes more objective and standardized. Because the ImPACT Test Battery is a computerized neuropsychological test program, it is practical for athletic trainers and other clinicians. Large populations of athletes can be baseline-tested in a timely fashion. Other advantages of the computerized test battery are ease of administration, rapid scoring, and increased test-retest reliability (Broglio, Ferrara, Macciocchi, Baumgartner, & Elliot, 2007). Schatz et al. found that the ImPACT Test Battery is not subject to a practice effect as compared to other paper and pencil tests. The ImPACT software was determined to be sensitive enough to detect the acute effects associated with sustaining a concussion. In a study performed by Iverson, Lovell, & Collins in 2002, athletes who had sustained a concussion reported a greater number of symptoms, scored lower on the ImPACT battery, and the symptoms following the concussion were related to the observed decrease in performance on the ImPACT battery (Iverson, Lovell, & Collins, 2002). Schatz et al. compared the composite scores of the ImPACT Test Battery of recently concussed high school athletes to the scores of non-concussed high school athletes. The ImPACT scores for about 85% of

the cases correctly identified those participants who had sustained a concussion. The ImPACT Battery was found to have a sensitivity rating of 81.9% and a specificity rating of 89.4% (Schatz et al., 2006). These results demonstrate that the composite scores generated by the ImPACT Battery are useful in determining when an athlete is able to return to participation. Because the ImPACT Battery is able to identify neurocognitive changes related to concussions, it will be used to assess levels of neurocognitive functioning in this study. These levels of cognition will then be compared to the number of headers accumulated over each athlete's collegiate soccer career to determine if a relationship exists between the two.

Summary

Sport-related concussions are prevalent in the sport of soccer (Boden et al., 1998 & Comstock, 2010) and are of concern to the sports health care professional. Evidence from combative sports along with American football has suggested that repeated blows to the head are not always benign (Naunheim, Standeven, Richter, & Lewis, 2000). Repetitive insults to the head during purposeful heading as part of the sport of soccer need to be examined further. Although previous research has indicated no deleterious effects of acute bouts or one season of soccer heading (Putukian et al. 2000 & Kaminski et al. 2008), no studies have examined the effects over multiple playing seasons. After examining data following 3 years of collegiate soccer participation, no relationship was found between purposeful heading and measures of neuropsychological test performance in male collegiate soccer players. Additionally, there was no effect of field position on the level of cognitive functioning of the soccer athletes.