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Twenty-eight elite level soccer players (mean age, 20.9 ± 2.5 yrs) were randomly assigned to one of three experimental groups: Headers with mouthguard (n = 10), Headers with no mouthguard (n = 10), and Control (n = 8). Subjects in the two treatment groups performed 12 headers of soccer balls projected at 40 km/hr from an electric soccer ball-launching machine. Postural stability was evaluated using a Biodex Stability
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Assessment of the Acute Sensorimotor and Neurocognitive Effects of Repeated Heading of a Soccer Ball.

by

Skye Arthur-Banning

A THESIS

submitted to

Oregon State University

in partial fulfillment of the requirements for the degree of

Master of Science

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APPROVED:

Redacted for privacy

Major Professor, Representing Human Performance

Redacted for privacy

Chair of Department of Exercise and Sport Science

Redacted for privacy

Dean of Graduate School

I understand that my thesis will become part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my thesis to any reader upon request.

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Skye Arthur-Banning, Author
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It has taken many years; literally, to get this thing done and I could not have done it without several very important people in my life. I would like to thank my family for always sticking with me regardless of what decisions or lack of decisions I chose to make. I have felt so far away from you all, but you have made efforts to bring me close, even if that meant disrupting your plans at special holidays or times of the year for me. I love you Freckles, and know that you will be watching over me. You were always a quiet partner who would listen when I needed you to. I have felt never-ending love from all of you and I have always, and will always cherish that.

Thank you to grandma and grandpa who have believed in me, loved me, and taken me into their home every spring break for the last many years. The time we have spent together has been more important to me than you can ever know. I love you and pray every day that I can express even half of the love to my children and grandchildren that you have expressed to me. You both are an inspiration, and motivation for me to make you proud to call me your grandson. I hope and pray that I will have you both around for many years to come.

To Lisa Bunderson, for being the light of my life when I thought things were going dark. Your smile and cheer can bring me back from the deepest of depressing days. You make me a more rounded person, my weaknesses are your strengths, and I am glad that I can learn from that. I look forward to many more years together wherever that may be.
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To the many friends and classmates I have had throughout the years, thank you for allowing me the opportunity to learn from you, and to ask all the questions that you all were thinking but didn’t want to ask. I felt stupid more than once for asking the question that everyone else already knew the answer to, but you still allowed me to learn. Thank you.

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Above all, I thank the Lord for all the blessings in my life.
CONTRIBUTION OF AUTHORS

Dr. Rod A. Harter was involved in the development and design of this study. He also assisted in the writing and editing of the final manuscript. Wendith M. Stratton assisted in the administration and the data collection of the Wechsler Digit Span test.
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DEDICATION

This thesis is dedicated to my family
for their unconditional love
and belief in my abilities

Freckles, I can feel you watching over me
every day of my life
with your unconditional love.
I miss you.
Assessment of the Acute Sensorimotor and Neurocognitive Effects of Repeated Heading of a Soccer Ball

Abstract

Several recent studies have revealed that high caliber European professional soccer players often have diminished levels of neurological functioning, yet no study has been able to identify the specific aspect of soccer participation responsible for these decreases. In an effort to identify a source of mild traumatic brain injury present in everyday participation in soccer, this study investigated whether a single bout of heading a soccer ball would have acute detrimental, measurable effects on sensorimotor and neurocognitive functioning. We hypothesized that subjects would exhibit significant changes in postural stability, memory, and concentration immediately after an acute bout of repeated heading a soccer ball. Additionally, we evaluated the protective effect(s) associated with wearing a mouthguard while performing the acute bout of heading.

Twenty-eight elite level soccer players (mean age, 20.9 ± 2.5 yrs) were randomly assigned to one of three experimental groups: Headers with mouthguard (n = 10), Headers with no mouthguard (n = 10), and Control (n = 8). Subjects in the two treatment groups performed 12 headers of soccer balls projected at 40 km/hr from an electric soccer ball-launching machine. Postural stability was evaluated using a Biodex Stability System, while memory and concentration were assessed using Wechsler Digit Span (WDS) tests (digits forward and digits backward) in a 3 x 2 factorial ANOVA design (α = 0.05). There were no significant main effects or interactions among the three measures of postural stability scores in the three groups (p > 0.05). The WDS Forward group means ranged from 10.4 ± 1.8 to 13.5 ± 1.2 while the WDS Backward means ranged from 6.4 ± 1.1 to 7.7 ± 3.0, but were not different among the groups (p > 0.05). We concluded that a single bout of 12 soccer headers approximating the number of headers performed during a typical NCAA Division I-A soccer practice did not produce significant deficits in postural stability, memory, or concentration. While our findings are similar to several recent studies, we suggest that more sensitive measurement tools such as ImPACT neurocognitive testing and functional magnetic resonance imaging be utilized to determine the effects of acute as well as chronic exposure to headers in soccer players.
Chapter 1

Introduction

Soccer is the most widely played sport in the world, with over 200 million participants engaged in organized activities. In the United States alone, participation in the sport has increased from 2 million in 1987 to an estimated 16 million soccer players currently involved in the sport. While numerous physiological and psychosocial benefits are derived from soccer participation, soccer players are also exposed to a significant risk of injury. Injuries such as strains and sprains to the lower extremities occur with regularity in soccer, yet the impacts of head injuries and concussion like symptoms are relatively less known.

The NCAA 2000-2001 Injury Surveillance System (ISS) report revealed that concussions accounted for over 10% of all men's soccer injuries, with an associated injury game rate of one injury every 3.7 games in the sport. Similarly, intercollegiate women soccer teams were likely to average one injury in every 3.8 games played with 13% of all injuries coming from concussions.

One unique aspect of soccer is the skill known as heading, or the purposeful use of the head for advancing and/or controlling the ball. In the process of heading the ball in both offensive and defensive situations, players often collide with one another and/or the soccer ball. Boden et al. suggested that the neurological deficits found among seven men's and eight women's NCAA soccer teams in the Atlantic Coast Conference, were the result of direct, traumatic cerebral concussions caused by making contact with either an opponent's head (28%), the ball (24%), an elbow (14%), or the ground (10%). These impacts, and the resulting concussions and mild traumatic brain injuries (MTBI) have
been cause for concern in soccer in recent years because of the significant neurological deficits that are being exhibited in veteran players.\textsuperscript{7,8,11,12}

Tysvaer and Storli (1989)\textsuperscript{11} reported that 37 (54\%) of their subjects, active soccer players in Norwegian first division leagues, complained of acute MTBI symptoms such as headache, dizziness, irritability, and disorientation. These and other MTBI symptoms were observed in the majority of players participating in soccer matches. These findings demonstrate the importance of determining whether the act of heading a soccer ball causes an MTBI. In several studies, it has been noted that an athlete who has sustained one MTBI has a four-fold greater risk of sustaining a subsequent MTBI.\textsuperscript{13,14}

Porter and O’Brien (1994)\textsuperscript{15} suggested that mouthguards reduced the number of head injuries, and thus the associated MTBI’s in rugby and hockey players. While it is recognized that impact forces from heading in soccer are from the forehead, additional investigations are needed to determine the extent of the relationship between episodes of concussion, and prevention of concussion with use of a mouthguard. If the use of a mouthguard can help reduce concussion-like symptoms in rugby and hockey players, then perhaps, even though the impact is from a different angle, a mouthguard can assist in attenuating some of the contra-coup forces that would otherwise reach the brain.

Previous studies have demonstrated depressed neurological functioning in high caliber soccer players, likely the result of several concussive episodes over the course of their career, or as a result of repeatedly heading the soccer ball in game and practice situations.\textsuperscript{8} No investigators have addressed the effect(s) of a single bout of heading in a practice or game-like situation. If significant sensorimotor and neurocognitive deficits
result from a single bout of heading, changes in soccer equipment and rules may be warranted to reduce or eliminate these injuries.

The purpose of this study was to investigate the effects of a single bout of heading a soccer ball while wearing a mouthguard or not on postural stability and cognitive functioning in amateur soccer players.

We hypothesized that subjects will exhibit a significant acute change in balance postural stability, as measured by the Biodex Stability System (Biodex Medical Systems, Shirley, NY). Additionally, subjects will exhibit a significant change in memory/concentration, as measured by Wechsler digit span scores (The Psychological Corporation, San Antonio, TX), immediately after an acute bout of heading a soccer ball. We also hypothesized that subjects who wore a mouthguard while participating in a bout of heading would demonstrate smaller changes in their postural stability and memory/concentration scores than their cohorts who were not wearing a mouthguard.

An abstract of the results of this thesis was submitted for presentation at the 2003 annual meeting of the American College of Sports Medicine, to be held in San Francisco, California. The Manuscript from this thesis will be submitted to the Journal of Athletic Training for review for publication.
Chapter 2

Assessment of the Acute Sensorimotor and Neurocognitive Effects of Repeated Heading of a Soccer Ball

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Manuscript to be submitted to the Journal of Athletic Training for Publication

November 2002
Abstract

Assessment of the Acute Sensorimotor and Neurocognitive Effects of Repeated Heading of a Soccer Ball

Objective: Several recent studies have revealed that high caliber European Professional soccer players often have diminished levels of neurological functioning, yet no study has been able to identify the specific source responsible for these decreases. This study investigated whether a single bout of heading a soccer ball would have acute measurable effects on sensorimotor and neurocognitive functioning that could possibly accumulate into the long-term effects observed among experienced soccer players.

Design and Setting: Twenty-eight elite level soccer players (mean age 20.9 ± 2.5 yrs) volunteered to participate were randomly assigned to one of three experimental groups: Headers with Mouthguard (n = 10), Headers with No Mouthguard (n = 10) and Control (n = 8). Measurements: Subjects in the two treatment groups performed 12 headers of soccer balls projected at 40 km/hr from an electric soccer ball-launching machine. Postural stability was evaluated using a Biodex Stability System, while memory and concentration were assessed using Wechsler Digit Span (WDS) tests (digits forward and digits backward) in a 2 x 3 factorial ANOVA design (α = 0.05). Results: There were no significant main effects or interactions among three measures of postural stability scores among the three groups (p > 0.05). The WDS forward group means ranged from 10.4 ± 1.1 to 13.5 ± 1.2, while WDS backward means ranged from 6.4 ± 1.1 to 7.7 ± 3.0, but were no different among the groups (p > 0.05). Conclusions: A single bout of 12 soccer headers, approximating the number of headers performed during a typical NCAA Division I-A soccer practice, did not produce significant deficits in postural stability, memory, or concentration. While our findings are similar to several recent studies, we suggest that more sensitive measurement tools such as ImPACT neurocognitive testing and functional magnetic resonance imaging be utilized to determine the effects of acute as well as chronic exposure to headers in soccer players. Key Words: Concussion, neurocognitive testing, postural stability.
Introduction

Soccer is the most widely played sport in the world, with over 200 million participants engaged in organized activities. In the United States alone, participation in the sport has increased from 2 million in 1987 to an estimated 16 million soccer players currently involved in the sport. While numerous physiological and psychosocial benefits are derived from soccer participation, soccer players are also exposed to a significant risk of injury. Injuries such as strains and sprains to the lower extremities occur with regularity in soccer, yet the impacts of head injuries and concussion like symptoms are relatively less known.

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We hypothesized that subjects will exhibit a significant acute change in balance postural stability, as measured by the Biodex Stability System (Biodex Medical Systems, Shirley, NY), and memory/concentration, as measured by digit span scores, immediately after an acute bout of heading a soccer ball. We also hypothesized that subjects who wore a mouthguard while participating in a bout of heading would demonstrate smaller changes in their postural stability, memory/concentration scores than their cohorts who were not wearing a mouthguard.
Methods and Materials

Subjects

Subjects for this study were recruited from the student and staff population at Oregon State University via campus flyers (Appendix A) and word of mouth. The 30 volunteers were required to meet the following criteria in order to be eligible to participate in the study: (a) played soccer at a collegiate level (NCAA Division I, community college, college-level sport club team) within the past 5 years; (b) no history of a concussion within the past calendar year, nor (c) no history of a serious concussion involving loss of consciousness that required hospitalization; (d) no involvement in a soccer practice or game two days prior to testing that required an atypical amount of heading of a soccer ball; (e) no active inner ear infection, or significant injury involving the hip, knee, or ankle that could negatively affect their postural stability; and (f) not currently under the influence of alcohol and/or illegal drugs.

The Oregon State University Institution Review Board for the protection of Human Subjects approved this study (Appendix B). All subjects provided informed consent (Appendix C) prior to participation in the study.

Subjects were asked to complete a screening questionnaire prior to qualifying for involvement in the study. The questionnaire required the subjects to answer a series of questions about their level of soccer play, their prior history of concussion episodes, their current injury status, and four questions about alcohol consumption. The use of alcohol is known to be associated with neurological changes; therefore, specific questions regarding the volunteer’s current use of alcohol was included in the questionnaire. These
four questions were adopted directly from the CAGE test that addresses issues such as cutting down on drinking, feeling of annoyance about one's drinking, feelings of guilt about one's drinking habits, and engaging in eye-opener drinking. A positive "yes" response to any of the four alcohol use questions disqualified a volunteer from participation in the study.

Two volunteers answered yes to one or more alcohol related questions on the CAGE test, and were excluded from further involvement in the study. A total of 28 subjects (19 male, 9 female) who ranged in age from 18 to 27 years (mean age 20.9 ± 2.5 yrs) met the criteria for inclusion in this study.

A Biodex Stability System (BSS) (Biodex Medical Company, Shirley, NY), was used for postural stability testing. The BBS uses a circular platform that freely tilts to 20 degrees from horizontal about the medial-lateral (ML) axis and simultaneously about the anterior-posterior (AP) axis to varying degrees. The BBS outcome measures selected for analysis were: (a) overall stability index (OSI), (b) anterior/posterior stability index (APSI), and (c) medial/lateral stability index (MLSI).

The OSI is a composite of the MLSI and the APSI values and is therefore sensitive to both the AP and ML measurements. All three indices are standard deviations that assess changes about the zero point on the axis. Specifically, the BSS stability indices represent the standard deviation of foot platform deflection (in degrees) from the level starting point during a particular test. A higher stability index number indicates a greater amount of movement from the subject's center of balance, whereas a lower stability index value indicates a lesser amount of sway or movement during the test.
The digit span forward test and the digit span backward test are subsections of the Wechsler Adult Intelligence Scale III (WAIS-III) (The Psychological Corporation, San Antonio, TX). Both Wechsler Digit Span tests were administered to our subjects by a trained Wechsler test administrator. According to the WAIS – III, the digit span forward is a measure of focused attention, while the digit span backward tends to be a better measure of the working memory.

The soccer balls used in this study were standard collegiate “size 5” synthetic balls properly inflated according to the manufacturer’s specification.

A JUGS soccer machine (The JUGS Company, Tualatin, Oregon) was used to project the soccer ball at a consistent velocity of 40km/h, a velocity established from our pilot study. The launch trajectory was such that the soccer ball was propelled approximately 16m from the machine and was still high enough in the air to be at the proper location for subjects to make contact on the ball with their foreheads.

**Pilot Study**

A radar gun (Supersonic Radar gun, The JUGS Company, Tualatin, Oregon) was used to quantify the average velocity of soccer balls being headed at an Oregon State University NCAA Division 1-A men’s soccer varsity practice. The 40km/h velocity selected for the JUGS soccer machine to launch the balls to be headed in this study accurately represented the ball velocities and subsequent soccer ball-human impacts present at this level of soccer competition.

The radar gun was further utilized in the small pilot study to determine whether the JUGS soccer machine was capable of projecting the soccer balls at a consistent repeatable velocity. In this pilot study, 25 consecutive trials with the soccer ball-
launching machine were evaluated; the average soccer ball mid-flight velocity was 39.8 km/h with a standard deviation of 0.42 km/h.

**Procedures**

Upon meeting the criteria for the study, subjects were randomly assigned into one of three groups: Headers with Mouthguard, Headers with No Mouthguard, or Control. Additionally, subjects were alternated between testing situations. The order of testing was counterbalanced so that the subjects were either required to perform postural stability testing on the BSS first, and memory testing (digit span second tests) second, or vice versa. This protocol was followed to control for any testing bias, learning effects, or loss of treatment effects due to the passage of time between testing situations.

The Postural stability testing consisted of stepping on the BSS plate with their dominant leg as a unilateral base of support. Subjects were asked to determine which leg they considered to be their strongest, and thus dominant leg. With this foot, they were required to stand in the middle of the circular BSS plate so that when they felt most balanced, the target marker would be in the center of the device’s LCD display screen. At this point, two pieces of tape were used to mark the foot position; one at the most distal point of the talus, and one at the most proximal point of the metatarsal in order to mark the foot position. This procedure was followed in anticipation that a subject might sway beyond his/her limits of stability and need to touch down with the non-dominant foot or step off the plate completely. During 2 of the 112 postural stability tests conducted (1.8%), a subject lost his/her original foot position and continued with the trials after the foot was repositioned using these marks.
The subjects were instructed to stand as still as possible on one foot while focusing on the Biodex LCD target screen. Each subject performed five practice trials to diminish the novel nature of the postural stability test and minimize any learning effects.

A BSS postural stability test has the possibility of nine different levels of difficulty, from easiest (Level 8 = least amount of tilt of the circular force plate permitted) to most difficult (Level 0 = greatest amount of tilt of the circular force plate permitted). In our study, each postural stability test began on level 6 (not difficult) and completed on level 2 (more difficult) over a period of 20 seconds. We programmed the BSS to increase the level of difficulty every 4 seconds during the 20 second test, i.e. Level 6 for 4 sec; Level 5 for 4 sec; Level 4 for 4 sec; Level 3 for 4 sec; Level 2 for 4 sec.

Between trials, subjects were permitted to rest in a bipedal stance and by using the handrail for support as needed. Subjects were not permitted to change their dominant foot position on the Biodex testing surface.

After completing the five practice trials, subjects were asked if they had any questions about the testing procedure, and having answered the questions the pre-test proceeded. The pre-test consisted of 2 postural stability testing sessions, exactly the same as the previous 5 practice test sessions (level 6 to 2 for a period of 20 seconds). Between the first and second BSS pretest session, the test results were printed and the subject was allowed to rest approximately 30 seconds. The results of the two postural stability pretests were averaged for later statistical analysis.

The Wechsler digit span (WDS) forward and backward tests were done while sitting in a desk located in an indoor gymnasium. The trained administrator would explain the directions to the subject as per the test requirements and ensure that the
information was clear to the subject prior to test taking. The WDS-forward test was administered first, followed by the WDS-backward test. The subjects were not told that they would be receiving exactly the same numbers for their digit span posttest. A complete set of WDS directions are presented in Appendix E.

After completing both the BSS and the WDS pretests, subjects were led to another area of the gymnasium floor where a 1m by 1m square area was marked on the floor with tape. Subjects stood inside the square to ensure that they remained within the 16 m to 17 m range of the soccer ball-launching machine in order that the trajectory and velocity of the machine remained the same for all subjects. Variations in the height of the subject determined if they should stand near the front of the box or nearer the back of the box to perform the headers.

The subjects were instructed to head the soccer ball back toward the ball-launching machine with as much force as was required to cover the 16 to 17m distance. The principal researcher (SAB) launched a test ball and the subject was asked to catch the ball near the level where they wanted to head the ball. Small adjustments to their standing position were then made within the 1m by 1m box to ensure that they were going to be heading the ball in the proper position on their forehead. The subject was then asked if he/she was ready and the testing commenced. The dozen balls were launched in succession, 10 seconds apart, at a velocity of 40km/h. Any contact of the soccer ball with the head was to be counted as a trial even if direct contact with the forehead was not made. We concluded that any soccer ball contacting the head would transmit an impact force to the skull and brain. From the launching of the first practice
ball to the taking of the final (12th) header, the entire process required approximately 5 minutes to complete.

Subjects in the control group were simply informed that they were not going to be performing the bout of heading, but instead sat quietly for 5 minutes, the same amount of time that subjects in the other treatment groups needed to complete the acute bout of heading.

As previously described, each subject in the treatment groups received 12 soccer balls from the machine to be headed, one after another. Immediately following the testing session, the subject performed the posttests, repeating the postural stability tests and the digit span tests (forward and backward) in the same order used in their pretest. Posttests were recorded as soon as possibly following the acute bout of heading or 5 minute quiet period, as appropriate. The results of the two postural stability posttests were averaged for later statistical analysis.

Following the testing sessions, each subject was required to sit quietly for 5 minutes to determine if he/she was experiencing any headaches or other symptoms that may have occurred as a result of the testing. If the 5 minute period elapsed and the subject was symptom free, his/her phone number was verified and each was told that he/she would get a follow-up phone call the next day to inquire whether or not any new symptoms as a result of the heading testing such as headaches, dizziness, and other signs of concussion were present. For each subject, all data were collected in a single testing session that lasted approximately 45 minutes.
Study Design and Analysis

Five two-way factorial analysis of variance (ANOVA's) were employed to evaluate the data for statistically significant main effect differences and the interaction between the two factors, with alpha level set a priori at 0.05. The Tukey-Kramer post-hoc test was selected due to its robustness when dealing with unequal sample sizes in each group. The five dependent variables analyzed were the three Biodex parameters (OSI, MLSI, and APSI) and the two Wechsler digit span (WDS) tests (digits forward, and digits backward). For all three postural stability index measures (OSI, MLSI, and APSI) the two pretest postural stability scores were averaged, as were the two posttest scores to create the time factor. The two independent variables analyzed were Group: (a) Headers with Mouthguard, (b) Headers with No Mouthguard, and (c) Control group; and Time: (a) pretest, and (b) posttest.

To analyze the data, SPSS 10.0 (SPSS, Inc., Chicago, Illinois) was used to calculate the descriptive statistics, ANOVA tables, and test of assumptions.
Results

A total of 34 men and women volunteered to participate in this study. Based on the pretest screening for previous concussions, four volunteers were eliminated from the study. Two volunteers answered "yes" to one or more of the CAGE questions regarding alcohol consumption and were eliminated from the study. The 28 volunteers who qualified for participation in this study and were randomly assigned to one of three groups: Headers with Mouthguard group (n=10), Headers with No Mouthguard group (n=10), and Control group (n=10).

Twenty-four of the 28 subjects were varsity soccer players or former varsity college level soccer players. The four remaining subjects were participating in college level club soccer at the time of the study. Subject demographic data are summarized and presented in Table 1.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Mean</th>
<th>±SD</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (Years)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MG-In</td>
<td>22.3</td>
<td>3.1</td>
<td>18-27</td>
</tr>
<tr>
<td>MG-Out</td>
<td>20.8</td>
<td>2.0</td>
<td>18-25</td>
</tr>
<tr>
<td>Control</td>
<td>19.5</td>
<td>1.2</td>
<td>18-22</td>
</tr>
<tr>
<td>Age Grand Mean</td>
<td>20.9</td>
<td>2.5</td>
<td>18-27</td>
</tr>
<tr>
<td>Soccer Experience (Years)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MG-In</td>
<td>11.8</td>
<td>3.0</td>
<td>7-16</td>
</tr>
<tr>
<td>MG-Out</td>
<td>10.9</td>
<td>3.0</td>
<td>6-16</td>
</tr>
<tr>
<td>Control</td>
<td>11.7</td>
<td>2.4</td>
<td>7-14</td>
</tr>
<tr>
<td>Grand Mean</td>
<td>11.7</td>
<td>2.7</td>
<td>6-16</td>
</tr>
</tbody>
</table>

Note: MG-In = Headers with Mouthguard group, MG-Out = Headers with No Mouthguard group.
Postural Stability Test Results

The average BSS postural stability indices (pretest and posttest scores) are presented in Table 2. The OSI values ranged from a low (good stability) of 2.90 ± 1.02 in the Control group pretest to a high poor (stability) of 3.76 ± 1.79 in the Headers with Mouthguard posttest. No significant pretest to posttest differences were observed among the three experimental groups for any of the three BSS measures of postural stability (p > 0.05).

<table>
<thead>
<tr>
<th>Component</th>
<th>Category</th>
<th>Pretest</th>
<th>SD</th>
<th>Posttest</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>OSI Index</td>
<td>MG-In</td>
<td>2.99</td>
<td>1.51</td>
<td>3.76</td>
<td>1.79</td>
</tr>
<tr>
<td></td>
<td>MG-Out</td>
<td>3.15</td>
<td>1.04</td>
<td>3.57</td>
<td>0.96</td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>2.90</td>
<td>1.02</td>
<td>3.12</td>
<td>1.11</td>
</tr>
<tr>
<td>AP Index</td>
<td>MG-In</td>
<td>2.55</td>
<td>1.53</td>
<td>3.14</td>
<td>1.61</td>
</tr>
<tr>
<td></td>
<td>MG-Out</td>
<td>2.67</td>
<td>1.00</td>
<td>3.13</td>
<td>1.01</td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>2.41</td>
<td>0.88</td>
<td>2.44</td>
<td>1.24</td>
</tr>
<tr>
<td>ML Index</td>
<td>MG-In</td>
<td>1.68</td>
<td>0.48</td>
<td>2.22</td>
<td>0.90</td>
</tr>
<tr>
<td></td>
<td>MG-Out</td>
<td>1.99</td>
<td>0.58</td>
<td>1.83</td>
<td>0.42</td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>1.90</td>
<td>0.51</td>
<td>1.98</td>
<td>0.35</td>
</tr>
</tbody>
</table>

Note: OSI Index = Overall stability index, AP Index = Anterior/posterior stability index, ML Index = Medial/Lateral stability index, MG-In = Headers with Mouthguard, MG-Out = Headers with No Mouthguard.

Main effects results, listed in Table 3, for all three groups (OSI, ML, and AP) were not significant. The main effects results for the OSI were; \( F_{OSI}(1, 25) = 2.49, p = 0.13 \), for the M/L index were; \( F_{ML}(1,25) = 1.37, p = 0.25 \), and for the A/P index were; \( F_{AP}(1,25) = 1.48, p = 0.24 \) respectively. Similarly, there were no interaction effects between time and group for any of the three groups either with \( F_{OSI}(2,25) = 0.28, p = 0.76 \), \( F_{ML}(2,25) = 2.54, p = 0.10 \), and \( F_{AP}(2,25) = 0.32, p = 0.73 \) respectively. These
findings appear to be consistent with the mean scores illustrated in Table 2 where there are few discernable differences between mean scores between groups.

Table 3
Postural Stability Indices
ANOVA Summary Table

<table>
<thead>
<tr>
<th>Component</th>
<th>Source</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>OSI</td>
<td>Group</td>
<td>1.872</td>
<td>2</td>
<td>0.936</td>
<td>0.508</td>
<td>0.608</td>
</tr>
<tr>
<td></td>
<td>Time</td>
<td>3.080</td>
<td>1</td>
<td>3.080</td>
<td>2.489</td>
<td>0.127</td>
</tr>
<tr>
<td></td>
<td>Time * Group</td>
<td>0.697</td>
<td>2</td>
<td>0.349</td>
<td>0.282</td>
<td>0.757</td>
</tr>
<tr>
<td></td>
<td>Error</td>
<td>30.936</td>
<td>25</td>
<td>1.237</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ML Index</td>
<td>Group</td>
<td>0.774</td>
<td>2</td>
<td>0.387</td>
<td>0.978</td>
<td>0.390</td>
</tr>
<tr>
<td></td>
<td>Time</td>
<td>0.334</td>
<td>1</td>
<td>0.334</td>
<td>1.365</td>
<td>0.254</td>
</tr>
<tr>
<td></td>
<td>Time * Group</td>
<td>1.243</td>
<td>2</td>
<td>0.621</td>
<td>2.536</td>
<td>0.099</td>
</tr>
<tr>
<td></td>
<td>Error</td>
<td>6.125</td>
<td>25</td>
<td>0.245</td>
<td></td>
<td></td>
</tr>
<tr>
<td>AP Index</td>
<td>Group</td>
<td>2.731</td>
<td>2</td>
<td>1.365</td>
<td>0.784</td>
<td>0.467</td>
</tr>
<tr>
<td></td>
<td>Time</td>
<td>1.761</td>
<td>1</td>
<td>1.761</td>
<td>1.483</td>
<td>0.235</td>
</tr>
<tr>
<td></td>
<td>Time * Group</td>
<td>0.753</td>
<td>2</td>
<td>0.753</td>
<td>0.317</td>
<td>0.731</td>
</tr>
<tr>
<td></td>
<td>Error</td>
<td>29.696</td>
<td>25</td>
<td>1.188</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* p ≤ 0.05

(Note: OSI = overall stability index; ML index = medial-lateral index; AP index = anterior-posterior index)

Wechsler Digit Span Test Results

The average Wechsler digit span test results (pretest and posttest scores) are presented in Table 4. No significant pretest-to-posttest differences were observed among the three experimental groups for either of these measures of memory or concentration (p > 0.05). The WDS-Forward test mean values ranged from 13.5 ± 1.2 digits in the Control group posttest, to a low of 10.4 ± 2.0 digits recalled in the Headers with No Mouthguard group pretest-to-posttest. In contrast, the best WDS-Backward test mean
was observed in the Headers with Mouthguard group pretest (7.7 ± 3.0 digits) compared to a low of 6.4 ± 1.1 digits recalled in the Control group pretest.

<table>
<thead>
<tr>
<th>Component</th>
<th>Pretest Category</th>
<th>Pretest Mean</th>
<th>Pretest SD</th>
<th>Posttest Mean</th>
<th>Posttest SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>WDS-Forward</td>
<td>MG-In</td>
<td>11.4</td>
<td>2.2</td>
<td>11.2</td>
<td>2.7</td>
</tr>
<tr>
<td></td>
<td>MG-Out</td>
<td>10.4</td>
<td>1.8</td>
<td>10.4</td>
<td>2.0</td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>12.5</td>
<td>1.2</td>
<td>13.5</td>
<td>1.2</td>
</tr>
<tr>
<td>WDS-Backward</td>
<td>MG-In</td>
<td>7.7</td>
<td>3.0</td>
<td>7.6</td>
<td>2.8</td>
</tr>
<tr>
<td></td>
<td>MG-Out</td>
<td>6.5</td>
<td>1.8</td>
<td>7.3</td>
<td>1.9</td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>6.4</td>
<td>1.1</td>
<td>7.5</td>
<td>1.1</td>
</tr>
</tbody>
</table>

Note: WDS-Forward = digit span forward, WDS-Backward = digit span backward, MG-out = Headers with No Mouthguard, MG-in = Headers with Mouthguard.

Table 5 illustrates the factorial ANOVA table for the digit span tests both forward and backward. The WDS-Forward test was not significantly different within the main effect F(1,25) = 0.79, p = 0.38, or across groups indicating the interaction, F(2,25) = 1.44, p = 0.255. The WDS-Backward main effects were not significantly different F(1,25) = 3.39, p = 0.08, nor was the interaction between time and category, F(2,25) = 1.24, p = 0.306. Since both tests were found to be not significant, post hoc tests were not conducted.
Table 5
Wechsler Digit Span Test Variables
ANOVA Summary Table

<table>
<thead>
<tr>
<th>Component</th>
<th>Source</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>DS Forward</td>
<td>Group</td>
<td>1.872</td>
<td>2</td>
<td>0.936</td>
<td>0.508</td>
<td>0.608</td>
</tr>
<tr>
<td></td>
<td>Time</td>
<td>0.985</td>
<td>1</td>
<td>0.985</td>
<td>0.799</td>
<td>0.380</td>
</tr>
<tr>
<td></td>
<td>Time * Group</td>
<td>3.557</td>
<td>2</td>
<td>3.557</td>
<td>1.444</td>
<td>0.255</td>
</tr>
<tr>
<td></td>
<td>Error</td>
<td>30.800</td>
<td>25</td>
<td>1.232</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DS Backward</td>
<td>Group</td>
<td>0.464</td>
<td>2</td>
<td>0.232</td>
<td>0.52</td>
<td>0.950</td>
</tr>
<tr>
<td></td>
<td>Time</td>
<td>5.124</td>
<td>1</td>
<td>5.124</td>
<td>3.399</td>
<td>0.077</td>
</tr>
<tr>
<td></td>
<td>Time * Group</td>
<td>3.741</td>
<td>2</td>
<td>3.741</td>
<td>1.241</td>
<td>0.306</td>
</tr>
<tr>
<td></td>
<td>Error</td>
<td>37.688</td>
<td>25</td>
<td>1.508</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: DS Forward = Digit Span Forward, DS Backward = Digit Span Backward.
* p ≤ 0.05
Discussion

Several research studies have suggested that long-term neurological effects occur in college and professional soccer players. Boden et al.\textsuperscript{10} suggested that the deficits they observed were a result of direct traumatic cerebral concussions. Jordan et al.\textsuperscript{16} suggested that repeat heading of a soccer ball might increase the effects of other head injuries such as a concussion.

Our study endeavored to determine if repeated, acute exposure to heading of the soccer ball manifests into short-term disturbances in sensorimotor and neurocognitive abilities. We observed no significant differences between the two groups of subjects who were exposed to the acute bout of heading, and those subjects that were in the control group.

The findings suggest that the postural stability did not change under the conditions that we created. Guskiewicz et al.\textsuperscript{21} determined that postural stability deficits were significant in athletes who had experienced a concussive episode. Since our findings did not determine that postural stability changes were present, we could deduce that no concussive symptoms were present following the bout of heading a soccer ball.

Our results with regard to the Wechsler digit span tests are consistent with the findings of Guskiewicz, et al.\textsuperscript{22} They concluded that there was no significant difference of neurocognitive performance between collegiate soccer athletes with many heading exposures throughout the course of the season and non-soccer athletes, or the student non-athletes (controls). The group means in this Guskiewicz study were: WDS-Forward, 9.63, ± 1.51 for soccer athletes, 9.88 ± 1.60, for non-soccer athletes, and 9.75 ± 1.53 for
controls, similarly, for the WDS-Backward they were, 8.20 ± 2.05 for soccer athletes, 8.11 ± 2.21 for non-soccer athletes, and 7.60 ± 2.29 for controls. These values are similar to the results found in our study, which further supports our findings.

Similarly, Jordan et al.\textsuperscript{16} and Barnes et al.\textsuperscript{4} both concluded that proper heading technique did not result in any episodes of concussions or encephalopathies in their subjects. The episodes of concussions in soccer were more likely the result of acute head injuries while playing soccer, rather than bouts of heading.

Additionally, memory and concentration as tested in the digit span tests, and balance as evaluated with the BSS postural stability indices were not significantly different between the Header with Mouthguard group and the Header with No mouthguard group. Based on what is known about mouth guards, and where the impact must occur in order for them to be effective in reducing impact to the brain, this finding was somewhat expected. Our hypothesis regarding mouthguard efficacy was merely exploratory to determine if an impact force coming from the top of the head could be reduced through the use of a mouth guard. Several authors have recommended mouthguard use for soccer players since soccer is a contact sport. However, this suggestion was made to protect the players from impact forces that originate from other players, or running into the goalposts, rather than to reduce the forces of heading the soccer ball.\textsuperscript{2,5} Perhaps a more practical field study should be done to determine the effects of the use of a mouthguard on reducing concussions in soccer situations over the course of the season, such as those that the players experience on the field of play.

Green et al.\textsuperscript{5} and Barnes et al.\textsuperscript{4} both suggested that there appeared to be gender differences in symptoms likely as a result of greater ball to head size ratio, smaller mass,
and less neck strength. While it was not the intended purpose of this study, the results indicate no significant differences between males and females after a bout of heading. For example, keeping in mind that a lower score represents less deviation from center, and thus better balance, subjects post OSI means were: males = 3.65, females = 3.21, $F = 0.646, p = 0.429$. While certainly the females performed better on the balance testing overall, the differences between their pretest and posttest scores were measured, and in that measure the differences were not insignificant.

While the findings in this study were relatively consistent with other findings with regard to neurocognitive functioning in soccer players, there were a few aspects of this study we would refine for subsequent investigations. The learning curve was likely the largest downfall to our study. Although the subjects did do five initial balance tests prior to their actual two recorded pretest scores being done, it did appear that subjects continued to improve in their postural stability posttest scores. Even if the heading bout did not affect their balance, it would have been encouraging to see a plateau in testing scores so that we could conclude that there truly were no short-term neurological or sensorimotor effects. As it stands however, we cannot conclude that convincingly because some of the posttest scores were actually better than their pretest scores, which would indicate the learning effect was still taking place.

The most interesting fact was that nearly half of the subjects indicated verbally prior to their posttest that they did feel a bit dizzy, and did not think they were going to do as well on the balance testing. This study may have uncovered some interesting results if, in addition to the balance and digit span scores there was a short questionnaire that the subjects filled out pretest and posttest about how they felt about their balance,
memory, or concentration. A qualitative questionnaire may have been a better indication of the subject’s personal awareness and how it was affected after a single bout of heading of the soccer ball.

Similarly, more extensive and thus more sensitive neurocognitive testing beyond the Wechsler digit span tests may have revealed acute deficits following the bout of heading. In particular, the battery of neurocognitive tests included in the ImPACT\textsuperscript{TM} concussion test from the University of Pittsburgh Medical Center may have revealed short-term deficits in our sample population.\textsuperscript{23,24}

One suggestion to address the problem of motor learning may be to allow 10 trials of the BSS to be done prior to the two pretests being taken so as to allow for the learning effect to plateau out. However, the initial consideration for this was that there might be a degree of fatigue that would come into play. If subjects were asked to do 10 trials at 20 seconds each, and then 2 pretests, that would be a considerable amount of proprioceptive muscle testing and any posttest performance decreases may be from fatigue rather than from the actual treatment effect. A more sensitive test may also have decreased the learning effect and illustrated more of the treatment effects, if there were any to be determined.

Learning was a problem with the digit span tests as well but not so much a learning curve, but rather simple memory. The digit span test was initially designed for Wechsler Adult Intelligence Scale III\textsuperscript{19} and was not designed for use as a repeated measure. We used the same numbers (digits) in the pretest and the posttest, and it appeared that some subjects actually did better in their posttest scores because they remembered the numbers from the pretest. There should have been two different sets of
numbers of similar difficulty used for the pretest and posttest scores. This would have eliminated the memory component from pretest to post test trials and perhaps given a better indication as to the effects of the treatment.

Another limitation of this study was the number of elite level soccer players in our immediate geographical area. With additional high caliber soccer players participating in the study, our statistical power would have increased, and the chance of making a Type II error would be reduced.

Finally, it did appear that there was a problem with how we defined a heading situation. There were several circumstances where the ball would glance off the side of the head and impact was minimal yet it had to be counted simply because of our definition of a header in this study. Perhaps our definition of a header should have been a direct blow to the forehead, but the impact effects of a glancing-blow header can neither be quantified nor cancelled out, nor substituted by another “perfect” test repetition. The heading bout was designed to include 12 game-like contacts, yet the question became how we account for the ball brushing off the head and not affecting the results.

Perhaps the most important outcome of our study is to add support previous investigations that suggested that depressed neurocognitive functioning in soccer players is more likely a result of hitting their head on the ground, the goal post, or colliding with other players rather than from the acute effects of heading a soccer ball.

Future research investigations should first identify and then employ more sensitive testing measurements such as EEG while subjects are actually performing a heading bout. We suggest that future studies of the acute effects of heading be conducted using a true control group (individuals with no history of athletic participation), as well as
elite and non-elite soccer players who continue to be exposed to repeat heading bouts throughout the course of their seasons. Finally, it would be interesting to address the heading styles, and techniques that are associated with effective heading to determine if there are different techniques to heading the ball that may lend itself to more or less neurocognitive impact on the brain.

Summary and Conclusions

Our results indicated that there were no significant differences (p> 0.05) in BSS index pretest and posttest scores between those subjects that were exposed to the bouts of heading and those subjects that were not. Similarly, there were no significant differences in these same two groups on the Wechsler Digit Span tests pre and posttest (p> 0.05). There were also no significant differences between subjects who wore a mouthguard while performing the headers and subjects who did not wear a mouthguard (p> 0.05).

Our findings suggest that subjects did not experience any significant decrements in postural stability, memory, or concentration as the result of an acute bout of heading a soccer ball. Additionally, we concluded that the heat-molded mouthguard we employed had no immediate beneficial effects on postural stability, memory, or concentration when assessed before and after a single bout of soccer ball heading.
REFERENCES


APPENDICES
APPENDIX A

Recruitment Flyer
Competitive Soccer players wanted!!

If you have played competitive soccer for a:
• Four Year University
• Community College

within the last 5 years......We want you!!!

Volunteer to be a participant in a study at OSU

Research will focus on the benefits of mouthguard use while heading the ball

For more information, contact
Skye Arthur-Banning
at 737-3569
APPENDIX B

IRB Approval
APPLICATION FOR APPROVAL OF THE OSU INSTITUTIONAL REVIEW BOARD (IRB)
FOR THE PROTECTION OF HUMAN SUBJECTS

Principal Investigator: Rod A. Harter
E-mail: rod.harter@orst.edu
Department: Exercise and Sport Science
Phone: 737-6801

Project Title: Assessment of the Acute Neurological and Cognitive Effects of Repeated Heading of a Soccer Ball

Present or Proposed Source of Funding: College of Health and Human Performance

Type of Project: Faculty Research Project

Student Project or Thesis: Skye Arthur-Banning
E-mail: bannings@ucr.orsu.edu
Student's mailing address: EXSS Dept., Langton Hall, Corvallis, OR 97331

Type of Review Requested: Exempt

The Oregon State University Institutional Review Board (IRB) for the Protection of Human Subjects is charged with the responsibility of reviewing, prior to its initiation, all research involving human subjects. The Board is concerned with justifying the participation of subjects in research and protecting the welfare, rights and privacy of subjects.

All material, including this cover sheet, should be submitted IN DUPLICATE to the Research Office, Kerr A312. Please call x7-0670 if you have questions. The following information must be attached to this form with each item identified and addressed separately or the application will be returned without review.

1. A brief description (one paragraph) of the significance of this project in lay terms.
2. A description of the methods and procedures to be used during this research project. Outline the sequence of events involving human subjects.
3. A description of the benefits (if any) and/or risks to the subjects involved in this research.
4. A description of the subject population, including number of subjects, subject characteristics, and method of selection. Include an advertising, if used, to solicit subjects. Justification is required if the subject population is restricted to one gender or ethnic group.
5. A copy of the informed consent document. The informed consent document must include the pertinent items from the "Basic Elements of Informed Consent" and must be in lay language.
6. A description of the methods by which informed consent will be obtained.
7. A description of the method by which anonymity or confidentiality of the subjects will be maintained.
8. A copy of any questionnaire, survey, testing instrument, etc. (if any) to be used in this project.
9. Information regarding any other approvals which have been or will be obtained (e.g., school districts, hospitals, cooperating institutions).

Signed: [Signature]
Date: April 15, 1994

*NOTE: Student projects and theses should be submitted by the major professor as Principal Investigator.
APPENDIX C

Informed Consent
Department of Exercise and Sport Science
Informed Consent Document

A. **Title:** Assessment of the Acute Neurological and Cognitive Effects of Repeated Heading of a Soccer Ball

B. **Investigators:** Skye Arthur-Banning,
Rod A. Harter, PhD, ATC

C. **Purpose:** I have been informed that the purpose of this research is to determine if there are short term effects associated with heading a soccer ball, and the role a mouthguard might play

D. **Procedures:** I understand that as a participant in this study the following things will happen:

1. **Pre-Study Screening**
   a. If I have not played soccer at a collegiate level (4 year university, community college, or sport club team) in the past 5 years I will not be asked to participate in this study.
   b. If I have had a serious concussion that caused me to be hospitalized I will not be asked to participate in this study.
   c. If I have had a concussion in the last year I will not be asked to participate in this study.
   d. If I currently have an injury that involves my hip, knee, or ankle that may also affect my balance I will not be asked to participate in this study.
   e. If I have been involved in a soccer practice or game in the last two days that involved a lot of heading of a soccer ball I will be asked not to participate in this study.
   f. If I am currently under the influence of alcohol and/or drugs I will be asked to not participate in this study.

2. **What participants will do during the study.**
   a. My participation will involve taking a balance test and 2 memory tests before and after a series of 12 headers 10 seconds apart, in which I will be heading a soccer ball. I will perform this skill with or without the use of a mouthguard depending on the group to which I am assigned. There is a possibility that I may be assigned to the control group, in which case, I will not be required to perform any heading skills at all.
3. **Foreseeable risks or discomforts.**
   a. I understand that there are possible discomforts to me if I agree to participate in the study. They may include; slight headache, minor dizziness, brief loss of memory or concentration, temporary depression, and minor irritability.

4. **Benefits to be expected from the research.**
   a. I understand that the possible benefits of my participation in the research are going to begin to address some of the possible explanations for long-term deficits exhibited in professional soccer players. A mouthguard may assist in reducing symptoms, and could be implemented into youth leagues as a rule at some point.
   b. I understand that as compensation for my participation, I will receive $10.00 for completion of testing session and will be given a mouthguard if I have not already been given one.

5. **Alternative procedures or course of treatment**
   a. There are no feasible alternative procedures available for this study.

E. **Confidentiality.**
   1. I understand that the results of the research study may be published but that my name or identity will not be revealed. In order to maintain confidentiality of my records, the researcher will assign a number to me, and all analysis will be of this coded data. The only persons who will have access to this information will be the investigators.

F. **Compensation For Injury.**
   1. I understand that Oregon State University does not provide a research subject with any compensation for medical expenses in the event of an injury. Health insurance can be purchased from Student Health Services at my own expense if I so choose.
   2. I understand that in case of injury I can expect to receive the following treatment or care which will be provided at my expense: I will be given the appropriate first aid attention by a certified first aid administer (Skye Arthur-Banning), unless profession medical staff are required, in which case proper medical staff will be notified to respond.
   3. I understand that I will receive a phone call one day after my testing session to ensure that I am not experiencing any delayed effects.

G. **Voluntary Participation Statement**
   1. I understand that my participation in this study is voluntary, and understand that I may withdraw my consent and discontinue participation at any time without penalty or loss of benefit to myself. I understand that if I withdraw from the study before it is completed, I will not receive the $10.00 compensation, nor will I be issued a mouthguard.
E. If You Have Questions.

1. I have been informed that any questions I have about the research study or my participation in it, before or after my consent, will be answered by Skye Arthur-Banning, 131 Langton Hall, Corvallis, OR, 737-3569, or Dr. Rod Harter, 226 Langton Hall, 737-6801.

2. If I have questions about my rights as a subject/participant in this research, or if I feel I have been placed at risk, I can contact Mary Nunn, Director of Sponsored Programs, OSU Research Office, (541) 737-0670.

My signature below indicates that I have read and that I understand the procedures described above and give my informed and voluntary consent to participate in this study. I understand that I will receive a signed copy of this consent form.

Signature of subject (or subject’s Legally authorized representative) ____________________________ Name of Subject ____________________________

Date Signed ____________________________

Subject’s Present Address ____________________________ Subject’s Phone Number ____________________________

Signature of Investigator ____________________________ Date Signed ____________________________
APPENDIX D

Stability System Numeric Report Example
STABILITY SYSTEM NUMERIC REPORT

RIGHT FOOT

TEST PARAMETERS
INITIAL STABILITY LEVEL: 6
END STABILITY LEVEL: 3
TEST DURATION: 5 MINUTES, 20 SECONDS
TARGET TRACK: ON

PATIENT STATISTICS
WEIGHT: 160 POUNDS
HEIGHT: 66 INCHES

RIGHT HEEL POSITION: C10
RIGHT FOOT ANGLE: 0 DEGREES

TEST RESULTS
OVERALL STABILITY INDEX: 1.8
A/P STABILITY INDEX: 1.4
M/L STABILITY INDEX: 1.3
MEAN DEFLECTION: 1.2
A/P MEAN DEFLECTION: 0.2
M/L MEAN DEFLECTION: 0.5
STANDARD DEVIATION: 0.5
A/P STANDARD DEVIATION: 0.7
M/L STANDARD DEVIATION: 0.4
PERCENT TIME IN ZONE:
A: 100% B: 0% C: 0% D: 0%
PERCENT TIME IN QUADRANT:
I: 10% II: 11% III: 10% IV: 61%

PERCENT TIME IN ZONE-QUADRANT CHART

<table>
<thead>
<tr>
<th>QUADRANT</th>
<th>A(0-5)</th>
<th>B(6-10)</th>
<th>C(11-15)</th>
<th>D(16-20)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>12%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>II</td>
<td>11%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>III</td>
<td>10%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>IV</td>
<td>61%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
</tr>
</tbody>
</table>

EYES OPENED OR CLOSED:
EYES POSITION:
HEAD MEASURE:
ARM POSITION:
HABITIST:
COMMENTS:
APPENDIX E

Wechsler Digit Span Test
8. Digit Span

Materials

Digits Forward and Digits Backward Items in Manual and on Record Form

Description

Digit Span is composed of two tasks administered independently of each other: Digits Forward and Digits Backward. On both tasks, the examiner reads a series of number sequences to the examinee. For each Digits Forward item, the examinee is required to repeat the number sequence in the same order as presented. For Digits Backward, the examinee is required to repeat the number sequence in the reverse order.

General Directions

The two parts of Digit Span—Digits Forward and Digits Backward—are administered separately. Administer Digits Backward even if the examinee obtains a score of 0 on Digits Forward.

Administer both trials of each Item even if the examinee passes Trial 1.

Read the digits at the rate of one per second, dropping your voice inflection slightly on the last digit in the sequence. Pause to allow the examinee to respond.

Digits Forward

Start

Trial 1 of Item 1

Discontinue

Discontinue after a score of 0 on both trials of any item.

Item Instructions

Before administering Trial 1 of Item 1, say:

I am going to say some numbers. Listen carefully, and when I am through, I want you to say them right after me. Just say what I say.
### Digits Backward

#### Start
- Trial 1 of Item 1:

#### Discontinue
- Discontinue after a score of 0 on both trials of any item.

#### Item Instructions
- **Say:**
  
  Now I am going to say some more numbers. But this time when I stop, I want you to say them backward. For example, if I say 7-1-8, what would you say?

  If the examinee responds correctly (9-1-7), say:
  
  That's right.

  If the examinee responds incorrectly, provide the correct response and say:
  
  No, you would say 9-1-7. I said 7-1-8, so to say it backward, you would say 9-1-7. Now try these numbers. Remember, you are to say them backward: 3-4-8.

Do not provide any assistance on this example or any of the items. Whether or not the examinee responds correctly (i.e., 8-4-3), proceed to Trial 1 of Item 1.

<table>
<thead>
<tr>
<th>Item</th>
<th>Trial</th>
</tr>
</thead>
</table>
| 1.   | Trial 1: 1-7  
      | Trial 2: 6-3  |
| 2.   | Trial 1: 5-8-2  
      | Trial 2: 6-9-4  |
| 3.   | Trial 1: 6-4-3-9  
      | Trial 2: 7-2-8-6  |
| 4.   | Trial 1: 4-2-7-3-1  
      | Trial 2: 7-5-8-3-6  |
| 5.   | Trial 1: 6-1-9-4-7-3  
      | Trial 2: 3-9-7-2-4-8-7  |
| 6.   | Trial 1: 5-9-1-7-4-2-8  
      | Trial 2: 4-1-7-9-3-8-6  |
| 7.   | Trial 1: 5-8-1-9-2-6-4-7  
      | Trial 2: 3-8-2-9-5-1-7-4  |
| 8.   | Trial 1: 2-7-5-8-6-2-5-8-4  
      | Trial 2: 7-1-3-9-4-2-5-6-8  |

#### Scoring
- Each item is scored 0, 1, or 2 points as follows:
  
  - 2 points if the examinee passes both trials
  - 1 point if the examinee passes only one trial
  - 0 points if the examinee fails both trials

Maximum Score on Digits Forward: 16 points

Maximum Score on Digits Backward: 14 points

Maximum Score on Digit Span: 30 points
APPENDIX F

Subject Questionnaire
Questionnaire

Subject #______

1. Name ___________________________ Phone # ________-

2. Age ________

3. Sex ________

4. I have not played soccer at a collegiate level (4 year university, community college, or sport club team) in the past 5 years.
   Yes ________ No ________

5. I have had a serious concussion that caused me to be hospitalized.
   Yes ________ No ________

6. I have had a concussion in the last year.
   Yes ________ No ________

7. I currently have an injury that involves my hip, knee, or ankle that may also affect my balance.
   Yes ________ No ________

8. I have been involved in a soccer practice or game in the last two days that involved a lot of heading of a soccer ball.
   Yes ________ No ________

9. I am currently under the influence of alcohol and/or drugs.
   Yes ________ No ________

10. Have you ever felt you should cut down on your drinking?
    Yes ________ No ________

11. Have people annoyed you by criticizing your drinking?
    Yes ________ No ________

12. Have you ever felt bad of guilty about your drinking?
    Yes ________ No ________

13. Have you recently had a drink first thing in the morning to steady your nerves or to get rid of a hangover?
    Yes ________ No ________
APPENDIX G

Review of the Literature
REVIEW OF THE LITERATURE

Soccer is the most widely played sport in the world, with over 200 million participants of all ages engaged in some form of organized competition. All ages from youth to over 50 categories are regularly organized in recreation programs around the world, and the World Cup of soccer is typically the most widely watched soccer event in the world every four years. The Federation Internationale de Football Association (FIFA), the world governing body of soccer, has a committee that is constantly involved in reviewing and rewriting the rules of soccer. Obviously, safety of the participants, and flow of the game would be a major cause for concern, and reason to possibly modify rules according to the suggestions of what research might determine.

In recent years, there has been much discussion about concussions in soccer, and more specifically, causes of concussions in soccer. The NCAA news in March of 2001 published a report that described the most recent fall sports, with a highlight featured story on head injury, specifically focusing on player contact injuries. In Men’s intercollegiate soccer, 10% off all game injuries were determined to be concussions or the participants were exhibiting concussion like symptoms. Similarly, 13% of game injuries in Women’s soccer could be attributed to concussions. This figure is up three percent from the 1999 NCAA injury report.

Concussions in soccer are caused by many different collisions, many of the obvious reasons such as participants hitting their head on the goal post, the ground, or making contact with other players appear to be reasonably easy to keep track of, as there is typically one single impact that can be attributed to the concussion. Smaller, less invasive obvious impacts to the head however could potentially have significant
detrimental effects if the exposures are sufficiently frequent. Since one intentional skill in soccer is heading the ball, which requires using the frontal lobe of the skull to propel the ball through the air, this could possibly provide the small, multiple, repeated yet frequent “doses” of heading that could potentially have an impact on the brain. Additionally, these smaller, less invasive and potentially misdiagnosed concussions could not be easily determined, and thus are not likely part of the percentages listed above in the NCAA study.

Previous investigators have reported that neurological deficits have been found in retired European professional soccer players, yet little is known about what some of the causes of these deficits may be. Evidence might suggest that it could simply be the yearly, repeated exposure to these previously reported percentages, or similar percentages in other leagues that would potentially expose a professional soccer player to several concussive episodes over the course of their careers. There has been some discussion about the effects of heading a soccer ball over and over again, and the sort of “punch drunk” syndrome that may come as a result. Because of this growing debate, it appeared necessary to at least attempt to address some of the factors associated with such high concussive rates in soccer, and the neurological deficits that have been identified in retired professional soccer players.

The major areas of the literature that would contribute to a better understanding of the effects of heading a soccer ball are listed as follows: Head injuries in soccer, Concussion and brain injury incidence in soccer, concussion in sport, Concussions, Second impact syndrome, Postural stability, Neuropsychological aspects of concussions, The Biodex Stability System, and Mouthguards.
Head Injuries in Soccer

The most recent article by Guskiewicz, Marshall, Broglio, Cantu, and Kirkendall\textsuperscript{22} attempted to address the high incidence of cerebral concussions in soccer, and whether or not their high levels had any effect on chronic neuropsychological dysfunction in NCAA soccer athletes as compared to other athletes, and non-athletes. Interestingly enough, they did not find any significant differences between soccer athletes and any of the other groups, even though the soccer athletes did exhibit a higher incident of concussive episodes over the course of the season.

Similarly, Putukian, Echemendia, and Machin\textsuperscript{6} attempted to address the specific effects of heading a soccer ball before and after practice situation not taking into account any previous concussive episodes that may or may not have occurred. Their approach appears to be a more specific in addressing the issue of heading with regard to the neurocognitive deficits. Putukian et al.\textsuperscript{6} also determined that the there were no differences between the control group and the groups that were exposed to the soccer practice situations, and thus they were able to conclude that heading the soccer ball does not lead to short term changes in ones cognitive functioning. Nonetheless, there still was obviously a time gap between heading the soccer ball in practice and the actual post test measure which was done at the end of practice. With such a slight impact to the head, such as what heading a ball may provide, this span of time may or may not be long enough for an individual to recover from the "buzz" that one might feel after a hard header.
Several authors have suggested that perhaps the dose response rate could provide the answers as to what may result from repeated concussions in soccer, or repeat episodes in heading over an extended period of time. An exposure index to headers was developed to attempt to piece together the logic that certain positions on the soccer field are exposed to greater numbers of headers simply because of the nature of the game, such as the goalkeeper would not typically head the ball, whereas the defenders would head the ball rather frequently. The assumption being that if the position of the player, combined with the years of experience, their acute head injuries to date, and the teams they played for, which would indicate the level of play, and possibly in the case of an indoor team with 20 games a season as compared to a player on semi-professional team that may have 40 games per season, their exposure bouts of heading would be different. This index was able to determine that encephalopathy was more a function of acute concussions that were experienced rather than the repetitive actions, or exposures of heading a soccer ball.16

Although this appears to be rather straightforward evidence that even if there are some signs of dysfunction in some soccer players, which not all researchers agree with either, those signs are not attributable to heading of a soccer ball, there are at least an equal number of studies that report the belief that heading is one cause of these deficits and dysfunctions, thus causing the intense debate between the two theories of thought.

Most recently, Matser, Kessels, Lezak, Jordan, and Troost 28, and Matser, Kessels, Lezak, and Troost 29 indicated that significant levels of cognitive impairment and function, as compared to controls could be attributed to soccer participation. With regards to planning, soccer players scored 16% lower and 20% lower in memory tests
than the non-soccer control group. Interestingly enough, in the Matser et al. study, the number of concussion in soccer was inversely related to the performance scores on all six of the tests that were performed. This would seemingly indicate that concussive episodes certainly have an impact on the neurocognitive functioning of a soccer player. The more recent of the two Matser et al., attempted to determine if there was a distinction between the deficits found as a result of acute concussion, and deficits found as a result of heading, similar to the dose response index that Jordan et al. attempted to put together. Their conclusions were not able to pinpoint specifically whether heading of the soccer ball was the cause of the impairments and perhaps suggested that it was the combined effects of concussions and heading, but again were able to determine that there were deficits. This conclusion, as proposed by Matser et al., was consistent with Downs, and Abwender as well as several others that did attribute decreased level of cognitive performance on a series of testing scales, but could not attribute the deficits to one or the other.

Having determined that several bits of research have concluded that there are no differences in functioning between soccer players and other control type groups, that some research suggests that there certainly are differences. Scientists and physicians have not been able to determine the origin of these differences. There are also several bits of research that not only found differences but were able to attribute them specifically to bouts of heading.

Sortland and Tysvaer, suggested that the reason soccer players have central cerebral atrophy as demonstrated by the use of a CT scan, was due to their exposure to several thousand bouts of heading over the course of years, coupled with possible
concussions through the course of play. Matser, et al.\textsuperscript{1} went as far as to determine that in fact players position was making a difference in the testing results and concluded that defenders and forwards who would most likely head the ball much more often than midfielders and goalkeepers showed significantly lower testing scores than their teammates who did not head the ball as frequently.

An interesting link that has been attempted to be made with regard to much of this literature was an age factor. It is thought that perhaps the older individuals studied are the ones that appear to be demonstrating the deficits, and in some instances this is true. Many of the studies who are using the professional soccer players as subjects appear to be able to show cognitive functioning difficulties while many of the amateur, or university aged subjects are not demonstrating the deficits as easily.\textsuperscript{32} Perhaps this is because many of the deficits are as a result of long term exposure to the elements of the game such as concussions and heading and in the younger players, the impairments have simply not had enough time to manifest themselves yet.\textsuperscript{3} Perhaps the older players are exhibiting these deficits because of the poor equipment they used for so long such as the heavy leather balls that were even worse when they got wet. This, and other explanations may be plausible, but as it is clear, a definitive answer is yet to be determined, and greater amounts of research should be continued.\textsuperscript{33}

**Concussion and Brain Injury Incidence in Soccer**

There is little conclusive evidence regarding the mechanism by which heading of a soccer ball affects neurocognition or processing deficits in soccer players. What is much more definitively known is the prevalence of head injuries in soccer. The 2000
survey as part of the NCAA Injury Surveillance System made a special point to highlight the incidence of concussions in soccer. The leg and knee were the most common body parts that were injured accounting for between 55 to 60% of all injuries in men and women. Concussions accounted for between 10 to 13% of all game injuries in soccer, which is up slightly from the 1999 report.9,34

This figure appears to be relatively consistent throughout the country, and has changed little over the years. In fact, Keller et al.2 found that head and face injuries in 1987 accounted for 7% of injuries in professional players, and between 10-15% in youth players. It was suggested that the slightly higher incidence of head injuries among youth was the difference in technique expertise, and possibly the head to ball ratio for the younger players. Putukian, et al.35 determined that indoor soccer injuries were following a slightly lower trend of 5-6% concussion injuries per season.2 As early as 1981, Tysvaer and Storli were attempting to determine the incidence of head injuries in professional soccer players.36 They were able to ascertain that head injuries are common, yet very few of them were serious enough to warrant any sort of surgery, or hospitalization.

Several studies were able to ascertain information from various players who had participated in high levels of soccer for at least 10 years. The attempt was made to determine a player’s chance of sustaining at least one head injury over the course of their careers. While men and women percentages were different, it was determined that men had a 50% chance of sustaining a head injury over the course of a 10-year career and women had a 22% chance.4,37 This estimation may be a low estimation however as several studies found nearly 90% of players had a history of head injuries.4,5 Boden,
Kirkendall, and Garrett, determined that at least in NCAA soccer, the basic incidence of concussion per team per season was 0.96, which indicates that basically every team will have at least one player on their team that will experience a concussion over the course of the season.

Finally, Green and Jordan were able to compile the NCAA concussion rates per 1000 athlete exposures from the years 1991 to 1996. The values ranged from 0.15 all the way up to 0.46 per 1000 exposures. Perhaps the most alarming figure was the comparison to American football concussion rates. These values ranged from 0.22 to 0.38 per 1000 exposures, which would indicate that soccer is at the very least comparable in terms of concussions, and in some years, actually exceeded football. Alarmingly enough, Boden, et al. suggested that this could be as high as 0.6 per 1000 exposures in males and 0.4 per athlete exposures for females.

Concussions in Sport

Growing concerns about concussions have resulted largely from the increases in literature about the potentially devastating effects of repeat concussions, and the increase of concussion like symptoms in many different sports. While head injuries occur in virtually any sport and at any level of competition, athletes engaging in contact sports have a greater risk of experiencing a concussion in their sports. In 1990, there were approximately 250,000 concussions in high school football alone. Roberts, suggested that high school football players have face a 20% risk of concussion every season, and high school hockey players a 10% risk. Given the fact that many players will play 3 or 4 years in high school, there is a relatively good chance that many of the players will have
experienced a concussion at some point in their playing careers. Roberts, Brust, Leonard, and Hebert\textsuperscript{40} attempted to address the injury rates for hockey in a three day, 31 game tournament. The rates were seemingly high, but perhaps eerily accurate. In this 31 game tournament, there were 273.8 injuries per 1000 player hours. Similarly, in these 31 games there were 5 reported concussions, which would indicate one concussion for every six games of play.

Ommaya, Ommaya, and Salazar\textsuperscript{41} looked at the medical records at a major medical institution in the United States. They found that of all the head injuries that were reported in the year 1992, 13\% of all of those head injuries were as a result of participating in some sporting activity. Of that 13\%, between 70-80\% of those injuries were results of concussion, while the remaining 20-30\% was a result of other oral facial injuries. Rugby, boxing and football were the most common causes of concusive injuries, with soccer, basketball, and baseball close behind. Finally, the greatest number of loss of consciousness (LOC) head injuries took place in soccer with nearly 25\% of the injuries that were reported resulted in LOC, which would lead us to believe some degree of concussion was present.

Fatalities are not at all uncommon as a result of concussions in sport either. Head injury is the leading cause of fatalities at most major ski resorts in the United States.\textsuperscript{42} Boxing is very similar with nearly 50-75\% of all professionals experiencing a concussion in every professional bout they participate in, and greater numbers of deaths in boxing are a result of concussions, than any other injury.\textsuperscript{42}

An interesting argument in the sports literature has to be when to allow an athlete to return to play, for it is well documented that allowing an athlete to return to play to
early puts the athlete at a 4 fold greater risk of experiencing a second concussion known as second impact syndrome. Also, the potential for death increases significantly as well.\textsuperscript{14,39,43,44,45} While the second impact syndrome will be discussed further in the concussion section of the literature, a wonderful explanation many of the currently used concussion scales is listed, and their return to play guidelines are also available following the symptoms that are associated with each degree of concussion. (Chart of Clinical Scales for Evaluating Head Injuries, 1998) (Appendix H). In the greater number of scales available, any sort of concussion symptoms that an athlete exhibits will prevent him/her from returning to play in the same event on the same day. While there are a few exceptions, this rule will generally hold true.

Unfortunately, athletes, and especially younger athletes will attempt to hide the effects of a concussion in an attempt to deceive the team physician so that the athlete will be permitted to return to play. As such, athletes must be constantly made aware of the dangers of repeat concussions, and the consequences of returning to play to early. Several individuals have suggested that a team trainer or doctor sequester a piece of a players equipment so as to ensure they are not able to return to play until they have been cleared to do so.\textsuperscript{14,39} Certainly if a minor is involved, the parents should be notified, and a doctors certificate stating that returning to play has been permitted should be formally provided to the coaching staff, and team medical staff.

Finally, there have been several suggestions regarding equipment, and rule changes that may reduce the incidence of head injuries and specifically concussions. Football perhaps should place a greater emphasis on proper technique, hockey should not allow body contact until 12 or 13 years old, soccer could use a lighter ball, pad goalpost,
and change some heading rules for younger ages, and lacrosse may reduce the stick
contact around the arms, in hopes that the mistaken contact with the head will occur less
often.\textsuperscript{14,46}

**Concussion**

There are several definitions of what a concussion might consist of, depending on
the classification scale being used. Kelly et al.\textsuperscript{38} defined concussion as "a trauma
induced alteration in mental status that may or may not involved loss of consciousness."
As it may appear obvious, there are three important aspects to defining a concussion like
state in this definition. The first, and most important would be the fact that it is a trauma-
induced event. With regard to sport, it would be beneficial to identify the causes of such
a traumatic event and make every effort to reduce the possibility of the event occurring.
Second in the definition is the alteration in mental status. This is perhaps the most
difficult symptom to detect because the individuals who have experienced a slight
concussion will have such minimally altered mental status that without the use of a CT
image of the brain, or some other extremely sensitive medical equipment, it is nearly
impossible to accurately determine on the field of play, although some tests are better
than others to administer at the site.\textsuperscript{14} Finally, the loss of consciousness should not be a
sole determining factor of concussions, since there are several lower grade concussions
that do not involve a loss of consciousness. Loss of consciousness is certainly a
determinant for the severity of a concussion but should not determine the presence or
absence of one.
A concussion typically occurs as a result of some trauma to the head or possibly the neck however, there are incidences such as a car accident, where no actual contact trauma has to occur but rather a jarring “whiplash” sort of event could also cause the forces necessary to cause a induce a concussion. This illustrates the importance of the action of the forces, rather than the actual contact of the head. Because the brain is its own mass, whenever the head comes to a stop quickly, which typically happens when there is contact, or to a person in a seatbelt for example, the heads motion typically stops, yet the brain continues to move within the skull. Within this scenario, this causes the brain to make contact with the skull, known as “coup”. The brain then attempts to return to its normal position, but due to the quick movement during the coup action, there is often a rebound effect known as a “contra-coup”, where the brain rebounds too fast, striking the opposite side of the skull as well. Such severe contact with the brain often causes a subdural hemorrhage or hematoma, a blood clot under the dura matter that can lead to much more severe problems such as brain swelling, and if not properly diagnosed and treated, death.\textsuperscript{47,48,49}

A less common, but equally as severe cause of concussions would be as a result of shear forces on the head and neck. These forces have an impact on the brain, but more specifically on the axons within the brain and brain stem. These axonal shear injuries are typically much more severe and can cause more permanent axonal injuries.\textsuperscript{50} Although the two most common causes of concussions are quite different, many of the determining factors, and associated symptoms are relatively similar in nature. It is also likely that the two mechanisms for concussion occur simultaneously to some degree.\textsuperscript{46}
There are many symptoms that have been used to determine whether an individual is showing signs of a concussion, or a concussive-like episode. Most practitioners who treat patients with head trauma will consider any transient impairment of brain function a concussion. The most common of symptoms would have to be: alteration in consciousness, disturbance of vision, equilibrium, concentration, memory, motor deficits, headaches, dizziness, nausea, confusion, amnesia, slowed mental processing, fatigue, poor judgment, and sleep disturbance.\textsuperscript{14,44,46,50,51,52,53,54,55}

Many of the classification scales that have been developed to determine the severity of concussion an individual has experienced are based on many of these symptoms. A summary of the more popular scales and the degrees of to which each scale is compatible with one another is listed nicely in the table entitled: Chart of Clinical Scales for Evaluating Head Injuries. The three most commonly used scales are the three level Colorado Medical Society Scale, the three level Cantu scale, with a fourth level addition by Roberts,\textsuperscript{39} that includes the bell ringer, and the 15 point Glasgow-Coma scale.

The Colorado Medical Society (CMS) Grading System is a three-grade system that appears to be the easiest to determine. Grade 1 or mild concussion consists of confusion without amnesia, and no loss of consciousness. Grade 2, or moderate concussion is characterized by the presence of mental confusion with amnesia and no loss of consciousness. A grade 3, or severe concussion is said to be present with any loss of consciousness. The associated return to play guidelines are also described and range from asymptomatic after 20 minutes, to one week, ending in rest for one month and asymptomatic for the last two weeks.\textsuperscript{26}
The Cantu Grading System for Concussion in Sports has rather similar criteria as the CMS, but with a few additions. According to the Cantu Scale, a Grade 1, or mild concussion would consist of no loss of consciousness, and/or post-traumatic amnesia less than 30 minutes with return to play in one week if asymptomatic. The Grade 2, or moderate concussion involves loss of consciousness for less than five minutes and/or post-traumatic amnesia lasting longer than 30 minutes but less than 24 hours. The primary return to play criterion is again for the patient to be asymptomatic for one week. Finally the Cantu Grade 3, or severe concussion category consists of loss of consciousness for more than five minutes, or post-traumatic amnesia for more than 24 hours. The major return to play criteria include at least one month off from practice and being asymptomatic for at least the last week. As stated earlier, Roberts added a pre-grade one level to the scale and called it the "bell ringer." This involves no loss of consciousness; no posttraumatic amnesia and return to play may take place after 30 minutes if asymptomatic. Interestingly enough a grade two on the Cantu Grading System would be a grade three on the CMS scale, so you can see there are some discrepancies. It would appear that the CMS scale appears to be a more sensitive measure of the milder forms of concussions, and the Cantu scale would be a more appropriate tool for the more severe forms of traumatic brain injury.

The third scale is the Glasgow Coma Scale and is based on three scoring components that when added together range from a minimum total of 3 to a maximum score of 15. The best eye response ranges from 1 to 4 points with "1" equating to no eye opening at all, and a score of "4" given to a patient whose eyes open spontaneously. The second component, verbal response, is graded on a scale of 1 to 5 points. A "1" on
the scale would be no verbal response at all, and a “5” would be oriented, and response is not confused, or slurred at all. The third category, motor response, is scored on a six-point scale. A score of “1” on the scale is no motor response at all, while “6” is obeys all commands, and the middle value, a “3”, would be subject is able to flex but with pain. Totaled together, a score of 12-15 would be considered “mild”, 8-12 would be “moderate”, and less than 8 would be “severe” concussion. Within each category there could also be degrees of mild, moderate, or severe as well, to be determined by the practitioner.

Second Impact Syndrome

The most serious cause for concern having addressed the acute symptoms of the concussion would be returning to play too early. Often times the bruises on the brain make it much more susceptible to future concussions, known as second impact syndrome. The typical scenario occurs when a person who has experienced a concussion sustains a second head injury before the symptoms associated with the first injury have fully subsided. The reason this injury is such a significant concern is because the forces required to induce the second impact to the brain are much less severe, and often involve the individual simply bumping into something, or receiving a blow to the side or chest. The athlete may appear stunned, but the brains vascular blood system becomes engorged remarkably fast, and intense intracranial pressure and subsequent brain stem failure can occur within two to five minutes. The bottom line that many articles have concluded is that athletes must not return to play with any symptoms of a concussion.
present. The risks far outweigh the benefits with nearly 50% mortality rate of individuals who are victims of second impact syndrome, and a morbidity rate nearing 100%.\textsuperscript{38,62}

Even if symptoms of concussion are no longer present, there is typically some scar tissue that results from the initial concussion impact. This point of weakness is certainly more susceptible to a repeat concussion in the future, and this is typically why a repeat concussion even after complete recovery from the initial concussion can cause cumulative effects. Scar tissue begins to build upon itself impairing brain function, and possible creating other lesions on the brain.\textsuperscript{49,50}

Finally, the literature suggests that after each concussive episode it takes the individual longer to fully recover from that episode that it did previously. For example, if an individual receive a grade one concussion on the CMS scale, their return to play time assuming they were asymptomatic would be 20 minutes. That same concussion occurring a third or fourth time in the season could remove the individual for the remainder of the season, up to six months. This again is a result of the cumulative effects of each successive concussive episode.\textsuperscript{26,51,63}

**Postural Stability**

It is widely accepted that loss of balance, loss of proprioception, and disequalibrium are one of the most consistent symptoms of minor head traumas. This is so because the areas of the brain that are generally damaged or impaired as a result of the concussions are the areas of the brain that maintain the equilibrium within the brain.\textsuperscript{5,13,51,63,64,65} It is estimated that up to 85% of individuals who experience head trauma will have balance difficulties.\textsuperscript{64} As such, even the most minor of head contacts
will typically illicit dizziness, and to some extent vertigo that can be visually, or mechanically measured. Additionally, Guskiewicz, et al. determined that the effects of minor head injuries on postural stability and balance will continue to illicit deficits even in the absence of amnesia or other post-concussion symptoms.

There are several tests that medical staffs typically used to determine if an individual was experiencing a sense of altered balance. The Romberg test would likely be the most common test of the eighth cranial nerve, the vestibulococchlear nerve, while tilt boards, balance beam, and simply pushing the person a bit to see how quickly they recover are less commonly used as evaluative measures of postural stability. The general purposes of these tests are to evaluate the patient’s ability to regain, or maintain their center of gravity over the body’s base of support. Moving the center of gravity beyond this base of support is known as testing your limits of stability. The typical limits of stability are approximately 12 degrees anterior/posterior positioning, and approximately 16 degrees medial/laterally. In most individuals, movement beyond these angles will generally cause a person to sway, reestablish their center of mass by repositioning their feet, or other parts of their body or fall. It is this sway technique of recovery that many clinicians attempt to measure the limits of postural stability with such equipment as the Biodex Stability System, the EquiTest System, The Chattecx Balance System.

There are two human sensory systems that contribute to balance control. The first system is the neurological system, which provides sensory processing and output that are imperative to any action, or cognitive behavior. The second system is the musculoskeletal system that provides the actual mechanism for movement and movement
response. In balance, the musculoskeletal system can relay information back to the neurological system, which then processes the information and signals to the musculoskeletal system to react to some action. However, the neurological system receives signals from visual cues, vestibular cues, and proprioception cues. In a situation where the effects of a concussion are still being exhibited, the neurological system may not be processing information as efficiently as it should be, and could be providing inaccurate signals to the musculoskeletal system, or simply take too long to process information in which case the other systems don’t have enough time to react to a change in center of mass.

Within the musculoskeletal system, the neck, pelvis and foot are considered to be the most important areas for balance. The neck is important for two reasons. The first of which is that the cervical mechanoreceptors serve as an important feedback mechanism to the neurological system about stability, but the neck is also a pivotal point in the body that can be used through movement as a righting response technique. This righting response acts as a counterbalance for the rest of the body, as well as a protecting response for our head should we fall, or begin to fall.

The pelvis appears to be an obvious area of importance for the balance of the body. The pelvis is typically where the center of mass, or center of gravity is and movement of the center of gravity can prevent or alter the stability of an individual. Typically, older individuals who have decreased flexion in their hips, and weakened stomach and lower back muscles are less able to manipulate their center of gravity quickly enough to prevent falls, or loss of balance.
Finally, the foot provides both stability and the base of support necessary. The saddle joint of the ankle allows for neuromuscular corrections to occur in nearly all directions. Any neurological impairment that does not provide adequate signals to the foot will alter the base of support throw off the entire kinetic chain.68

In measuring individual's balance, often the some sort of postural sway index is used. This index typically measures the degree to which the center of gravity moves within a specified range. The index provides a measurable level of postural sway that can be compared pre and post concussion. Some practitioners are even doing pre-season baseline testing to determine the "normal level of postural sway". Should an athlete experience a concussion throughout the season, there is sufficient information to make possible return to play decisions.51,52

Neuropsychological Aspects of Concussions

Cognitive dysfunctions are a common result of concussion experiences and are especially present up to one-week post concussion. The coup and contra-coup phenomenon has been shown to be the primary function of injury in a concussion. As such, the brain being bounced around has a severe impact on the parts of the brain that transmit signals. More specifically, axons can stretch, twist, bend or break, as can parts of the myelin sheath surrounding and insulating the axons can also be broken or torn causing possible misfiring or the axons, or contributing to the breakdown of the axons themselves.69 It is this axon degeneration, or injury that typically causes the symptoms that are associated with a concussion. Amnesia, unconsciousness, difficulties with
concentration, headaches, reaction time, and interruption in sleep patterns, attention and memory, language impairments, all can be associated with axon disruption. \(^{69,70,71}\)

Several of the most prominent and perhaps easiest components to measure with regard to axon degeneration and effects of head injuries are memory, concentration and reaction time. Digit span tests of some sort are rather common way of measuring memory and concentration. Several different test batteries such as the digit symbol substitution, the serial digit learning, and the digit symbol tests have been used in various studies, but they are all designed to measure the neurological sequelae of an individual. \(^{72,73}\)

Much of the research has been able to demonstrate that individuals who have experienced a concussive episode do tend to score lower on tests of memory, concentration, motor skills, IQ test components, and processing skills. Perhaps even more significantly, these tests are imperative in determining recovery rates in individuals who have experienced a concussion. It was determined that often individuals experience deficits up to one year post concussion, even if no obvious symptoms are present, although most individuals have recovered from the concussive episode about 3 months post concussion. \(^{69,74}\) Not all patients should be held to the same timetable as younger individuals have a faster recovery rate than older individuals, largely because of their ability to repair axon damage. \(^{69,74,75,76}\)

Rimel et al. \(^{77}\) were able to determine that as many as 50% of their subjects had complaints of frequent headaches, and memory deficits at 3 months post concussion. However, there are likely two factors that determine recovery rates more often than any other. The severity of concussion obviously would be one, where individuals who had
experienced a less severe concussion would have a fast recovery rate, but also previous history of concussions. Individuals who have experienced greater numbers of concussions tend to have a much slower recovery rate and exhibit more post concussion symptoms for a greater period of time.\textsuperscript{77,78}

**The Biodex Stability System**

The Biodex Stability System (BBS), (Biodex, Inc, Shirley, NY), is a computerized, circular platform system that reacts differently than the traditional force plate system. This platform allows measurements in two planes simultaneously (anteroposterior (AP) and mediolateral (ML). However, interestingly enough in a single leg stance, which is the typical protocol for the BBS, there is greater AP motion simply based on the anatomical factors of the foot.\textsuperscript{18} There is a greater possibility of movement in the AP plane then there is in the ML plane of the foot, and this should be taken into consideration when the index is viewed. Also, since the BBS provides an overall stability index (OSI) with a weighting of AP and ML as equal, it should be noted that these two values may not be equal, and perhaps OSI should not be used on its own, but rather in combination with the other two Biodex stability index scales, APSI, and MLSI.\textsuperscript{18}

Additionally, since the BBS could potentially be a motor memory kind of testing apparatus, it is suggested that at least five practice trials be performed prior to the actual testing protocol taking place.\textsuperscript{18}

Finally, Schmitz and Arnold\textsuperscript{18} determined that for a single leg decreasing platform stance, the BBS appears to be highly reliable when performed according to testing protocol. The OSI and APSI scales had reliability coefficients of 0.82 and 0.8 respectively, while the MLSI scales had a reliability coefficient of 0.43.
**Mouthguard**

Although mouth guards were originally designed to prevent oral injuries, their effectiveness in preventing concussion like episodes are growing.\(^{79,80,81}\) It has been widely accepted that mouth guards can be instrumental in reducing the effects of a blow to the head on the brain.\(^{83}\) This is such because the posterior segment of the mouth guard is able to separate the mandible and the maxilla and from one another therefore preventing the transmission of force from the lower jaw to the base of the brain.\(^{82}\)

Although most of the impacts to the head in soccer are applied to the top of the skull, there still could potentially be some force that would be dissipated from the cushioning effects of a mouth guard. One example of such device is the medium-sized Buy-Max mouth guard because of its elastically tensile proportions, and its ability to adequately separate the mandible from the maxilla.\(^{15,41}\)

**Summary**

Concussions are a common concern for athletes at all levels, but especially athletes who participate in contact sports. Selecting the appropriate measuring scale that would be appropriate for the specified sport continues to be extremely important when making return to play decisions about the athletes. Previous investigators have reported that soccer tends to be one of the sports where athletes are more prone to experience concussion episodes in game and practice situations, by making contact with an opponent's head, the goal post, the ground, and potentially the ball. One unique aspect of soccer is the purposeful use of the head to propel the ball in a forward direction. This
repeated head impact with the ball could potentially have effects on an individual's neurocognitive, and sensorimotor systems. As such, it would be beneficial to determine, and to continue to monitor, how heading of a soccer ball, and more generally if the effects of concussions in soccer can influence a participants daily activities of living such as postural stability, memory and concentration.
BIBLIOGRAPHY


APPENDIX H

Chart of Clinical Scales for Evaluating Head Injuries
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**CHART OF CLINICAL SCALES FOR EVALUATING HEAD INJURIES**

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**Possible carotid artery collapse**

**Possible paralytic negative scale**

**Possible death**