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A Preliminary Examination of Neurocognitive Performance and Symptoms Following a Bout of Soccer Heading in Athletes Wearing Protective Soccer Headbands

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This study compared changes in neurocognitive performance and symptom reports following an acute bout of soccer heading among athletes with and without protective soccer headgear. A total of 25 participants headed a soccer ball 15 times over a 15-minute period, using a proper linear heading technique. Participants in the experimental group completed the heading exercise while wearing a protective soccer headband and controls performed the heading

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exercise without wearing the soccer headband. Neurocognitive performance and symptom reports were assessed before and after the acute bout of heading. Participants wearing the headband showed significant decreases on verbal memory ($p = 0.02$) compared with the no headband group, while the no headband group demonstrated significantly faster reaction time ($p = 0.03$) than the headband group following the heading exercise. These findings suggest that protective soccer headgear likely does not mitigate the subtle neurocognitive effects of acute soccer heading.

KEYWORDS soccer heading, soccer headgear, neurocognitive performance

INTRODUCTION

Soccer is the most popular sport in the world, with more than 265 million participants worldwide (Fédération Internationale de Football). As the popularity of this sport increases, so does the concern for concussion. Concussions comprise approximately 5.8% (male) (Agel, Evans, Dick, Putukian, & Marshall, 2007) and 8.6% (female) (Dick, Putukian, Agel, Evans, & Marshall, 2007) of all injuries in collegiate soccer. Among the many mechanisms that cause concussion across all sports (e.g., head-to-head, head-to-ground, etc.), heading the soccer ball is a unique mechanism to the sport of soccer and regarded as an integral skill for successful play. Although heading is a skill that can be an asset, poor technique may place athletes at risk for injury. In response to these concerns, the use of protective soccer headbands have become a popular choice with the hopes of mitigating impact forces that occur with heading a soccer ball.

Soccer players sustain numerous impacts from the intentional heading of a soccer ball (Tysvaer & Storli, 1981). In a career of 300 games, a competitive soccer player will perform approximately 2000 headers (Matser, Kessels, Jordan, Lezak, & Troost, 1998). Older research involving amateur and professional soccer players indicated an association between cumulative heading and neurocognitive impairment (Matser et al., 1998; Matser, Kessels, Lezak, Jordan, & Troost, 1999; Matser, Kessels, Lezak, & Troost, 2001). A recent imaging study suggested that the impacts from soccer heading may be associated with changes in brain activation later in life (Koerte, Ertl-Wagner, Reiser, Zafonte, & Shenton, 2012).

The cumulative effects associated with an increased number of headers and concussions have been reported to be related to poor memory, planning, and visuoperceptual performance (Matser et al., 1998). Amateur soccer players scored 39% lower than normative values on planning tasks of neurocognitive function (Matser et al., 1999). Matser and colleagues (2001) reported that as the number of headers (per 1000) increased, scores for verbal memory,

visual memory and focused attention decreased in a sample of professional soccer players. Similarly, as the number of concussions increased, visuoperceptual processing and sustained attention scores also decreased (Matser et al., 2001). These researchers concluded that these impairments could be caused by a combination of concussions and the repetitive blows associated with heading (Matser et al., 1998, 1999, 2001). However, these studies did not employ baseline testing and failed to control for confounding variables (e.g. substance abuse) that could affect neurocognitive performance.

In contrast, other studies have not supported a deleterious relationship between soccer heading and decreased neurocognitive function (Matser et al., 1998, 1999, 2001; Putukian, Echemendia, & Mackin, 2000). Putukian, Echemendia, and Mackin (2000) examined the acute effects of heading on cognitive function and reported that soccer heading was not associated with acute changes in neurocognitive function. More recently, Kontos, Dolese, Elbin, Covassin, and Warren (2011) reported that heading exposure was not associated with differences in neurocognitive tests performance or symptoms. Together, these studies suggest that soccer players are not at risk for neurocognitive deficits associated with soccer heading.

In spite of these equivocal findings, preventative measures such as rule changes and the design of protective equipment have been made to protect soccer players from the potential negative effects of repetitive head impacts. Several manufacturers have developed protective soccer headbands that are purported to reduce concussion and the neurocognitive effects of soccer heading (if any exist). Manufacturers claim that these devices will decrease the force of head impacts and protect soccer players from head injuries (Full90, 2007). However, few studies to date have been conducted to compare changes in neurocognitive performance and symptom reports before and after an acute bout of soccer heading among athletes wearing and not wearing protective soccer headbands.

Similar to literature on soccer heading and neurocognitive performance, research examining the utility of soccer headbands in reducing heading impacts has provided unequivocal results (Broglia, Ju, Broglia, & Sell, 2003; Withnall, Shewchenko, Wonnacott, & Dvorak, 2005). Broglia et al. (2003) used a vertical force platform to evaluate the utility of three soccer headbands (Full90, Headblast, Protector). At 35 mph, these researchers concluded that protective headbands were effective in reducing the peak force impact of a soccer ball during ball-to-head impacts. Withnall et al. (2005) examined forces imparted to dummy head forms and reported that protective headbands were effective in reducing head-to-head impact; but failed to provide protection from ball-to-head impact. However, these studies have limited generalizability due to the use of force platforms and dummy head forms, which failed to consider neck strength and human reactions upon impact. Only one study has examined the effects of soccer headbands on reducing the likelihood of concussion. Delaney, Al-Kashmiri, Drummond, and Correa (2008) reported that players who wore a protective headband were less likely to have a

concussion than those who did not. However, this study did not control for exposure levels and did not account for player behavior.

Although previous studies have focused on evaluating soccer headbands' ability to dissipate force, no research has examined the utility of these headbands to mitigate potential neurocognitive impairment and symptom reports that may occur following an acute bout of heading. The present study is a preliminary examination of neurocognitive performance and symptom reports following an acute bout of soccer heading among athletes with and without protective soccer headgear.

METHODS

Design

A randomized experimental pretest/post-test design was used for this study. The independent variables were headband group (soccer headband, no headband) and time (baseline, post-test). The dependent variables were verbal memory, visual memory, processing speed, reaction time, and reported symptoms.

Participants

A total of 25 varsity ($n = 14$) and club ($n = 11$) collegiate soccer players participated in the study. Participant ages ranged from 18 to 23 years and all participants had a minimum of four years of soccer experience. Participants with a history of concussion (the past six months), learning disability, hyperactivity disorders, or migraine were excluded from participation. Participants were randomly assigned to headband or no headband groups. Twelve participants (five males and seven females) comprised the headband group and 13 participants (five males and eight females) comprised the no headband group. Groups did not differ on age ($t(23) = 0.49, p = 0.63$), height ($t(23) = 0.47, p = 0.64$), weight ($t(23) = 0.64, p = 0.53$), years of experience ($t(23) = 0.47, p = 0.65$), or previous concussion history ($t(23) = 0.59, p = 0.56$) (see [Table 1](#)).

TABLE 1 Demographic Information for Headband ($N = 12$) and no headband ($N = 13$) Groups

	Headband		No Headband	
	Mean	SD	Mean	SD
Age	20.42	1.88	20.08	1.61
Height (cm)	170.61	10.21	168.80	8.89
Weight (kg)	68.37	9.42	66.12	8.14
Years Experience	2.25	1.13	2.46	1.12
Previous concussion	0.58	0.52	0.46	0.52

* $p \leq 0.05$.

Instrumentation

NEUROCOGNITIVE TEST AND SYMPTOMS

The Immediate Post-Concussion Assessment Cognitive Testing (ImPACT) was used to assess neurocognitive function. ImPACT is widely used for concussion management and consists of three main categories: demographics, the Post-Concussion Symptom Scale (PCSS), and six neurocognitive test modules that yield composite scores of verbal memory, visual memory, processing speed, and reaction time. ImPACT uses parallel forms of design and word memory groups to control for practice effects. The reliability and validity of the ImPACT test has been previously published (Elbin, Schatz, & Covassin, 2011; Iverson, Brooks, Collins, & Lovell, 2006; Iverson, Lovell, & Collins, 2003, 2005; Schatz & Ferris, 2013; Schatz, Pardini, Lovell, Collins, & Podell, 2006; Schatz & Sandel, 2013).

SOCCER HEADING

A JUGS Soccer Machine was used to deliver soccer balls to be headed by participants in the present study. There are two speed dials located on the control panel, which allow for consistent ball speed to be achieved. The JUGS Soccer Machine has the capability to propel a soccer ball at speeds ranging from 0–100 mph.

PROTECTIVE SOCCER HEADBAND

The Full90 is a protective headband that is widely used by soccer players. The Full90 headband is comprised of protective material that surrounds the temporal, parietal, occipital, and frontal regions head (Withnall et al., 2005). Constructed of approximately 11 mm thick polyethylene foam (i.e., ForceBloc Foam), the Full90 headband is designed to mitigate forces imparted to the head (i.e., head-to-ball, head-to-head/body, head-to-ground) following contact associated with playing soccer.

Procedures

Approval for the study was granted from the University's Biomedical and Health Institutional Review Board (IRB) prior to data collection. Written informed consent was obtained from each participant prior to his or her voluntary participation in this study. Testing did not begin until athletes completed their competitive soccer season and had at least one week of rest from heading a soccer ball. A pilot test was conducted prior to beginning the testing phase of the current study. Additionally, informal feedback from

coaches, current players, and former players was given regarding the realistic properties of the experimental setting.

Participants reported to the computer testing room on a designated pre-arranged time and day. Written informed consent was completed at this time and each participant was randomly assigned to either the control group or experimental group. Participants were administered a baseline neurocognitive test prior to the start of the heading session. Participants then reported to a gymnasium, where they were instructed on proper heading technique, and allowed to watch five soccer balls launched from the JUGS machine to familiarize themselves with the speed of the ball. Participants in the experimental group were fitted with a Full90 headband.

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

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

A research assistant recorded the heading accuracy for each participant. A correct (i.e., successful) header was recorded when participants successfully headed the ball off the frontal region of the head. All other unsuccessful headers were recorded as incorrect. Once the heading exercise was complete, participants were immediately escorted back to the computer testing room for a follow-up administration of the neurocognitive test.

Data Analysis

All variables were analyzed for normality, with only baseline and post-heading total symptom scores showing skewness >1.0 . As a result, change scores (Δ) from baseline-to-post-heading were calculated, with the resultant skewness <1.0 for all dependent measures.

Change scores in neurocognitive performance and total symptom reports following the acute bout of soccer heading were evaluated with a two-group (headband, no headband) MANOVA. Box's M revealed equality of within-group covariance matrices ($p = 0.11$) and Levene's test revealed equality of

error variances on all dependent measures. The level of significance was set a priori at $p \leq 0.05$. All analyses were conducted using the Statistical Package for the Social Sciences (SPSS) version 20.1 (SPSS Inc., Chicago, Illinois). Cohen's d was documented as a measure of effect size for differences between headband groups on change in neurocognitive performance.

RESULTS

Heading Accuracy

There were no differences among the headband and no headband groups for the number of successful headers ($t(23) = 1.28, p = 0.21$) (Table 2). Participant statistics for the number of correct headers performed are presented in Table 2.

Neurocognitive Performance and Symptom Reports

The results of the MANOVA revealed a significant effect of headband group on neurocognitive performance change scores (Wilk's $\lambda = 0.55, F [5, 19] = 3.07, p = 0.034, \eta^2 = 0.45$). Subsequent univariate analyses revealed significant differences for verbal memory ($p = 0.02$) and reaction time ($p = 0.03$). A series of paired t-tests were performed to further explore this interaction, and the results indicated that the headband group performed significantly worse on verbal memory from baseline to post-test ($t(11) = 2.58, p = 0.03$). However, there were no significant differences on verbal memory for the no headband group from baseline to post-test ($t(12) = -1.22, p = 0.25$). In addition, the no headband group performed significantly faster on reaction time from baseline to post-test ($t(12) = 3.71, p = 0.03$). In comparison, the headband group did not demonstrate a significant difference in performance on reaction time from baseline to post-test ($t(11) = 0.30, p = 0.77$). There were no significant difference between groups for visual memory ($p = 0.26$), processing speed ($p = 0.83$) and total symptoms ($p = 0.64$). Means and standard deviations for each neurocognitive composite score and symptoms, as well as change scores and effect sizes are presented in Table 3.

TABLE 2 Comparison of Successful Headers for the Headband ($n = 12$) and No Headband ($n = 13$) Groups

	Mean	SD
Headband	12.83	1.70
No headband	11.70	2.63

* $p \leq 0.05$.

TABLE 3 Pre and Post-heading Descriptive Statistics for Neurocognitive Performance and Total Symptoms for the Headband ($n = 12$) and No Headband ($n = 13$) Groups

	Baseline		Post Heading	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Verbal memory				
Headband	0.90	±0.09	0.85 ^a	±0.12
No headband	0.85	±0.10	0.88	±0.10
Visual memory				
Headband	0.83	±0.11	0.80	±0.12
No headband	0.79	±0.12	0.82	±0.10
Processing speed				
Headband	47.09	±5.82	47.81	±7.18
No headband	42.64	±5.72	43.02	±6.50
Reaction time				
Headband	0.53	±0.06	0.52	±0.05
No headband	0.55	±0.05	0.52 ^a	±0.04
Total symptoms				
Headband	1.92	±2.58	2.00	±2.63
No headband	2.77	±6.84	3.46	±4.58

^a = significantly different from baseline ($p \leq 0.05$).

DISCUSSION

The purpose of the current study was to investigate the utility of the Full90 protective soccer headband in mitigating the neurocognitive effects and symptoms following an acute bout of soccer heading. Collegiate soccer players in the headband group demonstrated decreased performance on verbal memory compared with soccer players who did not wear the headband. Additionally, the no headband group showed a significant improvement in reaction time following the heading exercise. These findings suggest that the Full90 headband does not mitigate the subtle neurocognitive effects of heading.

The differences in the headband group may be attributable to the changes in the magnitude of sustained forces while wearing the headband, as reported in Broglio et al. (2003) and Withnall et al. (2005). These researchers concluded that the deformation of the ball across the protective headband was a key factor during impact, and could also be a factor in the current study. Withnall et al. (2005) suggested that for this device to offer better protection, it would need to be thicker and softer, to successfully reduce ball impact forces.

Proper heading technique involves the use of the frontal bone when striking the ball with the forehead at or near the hairline (Kirkendall & Garrett, 2001). Beneath the frontal bone lies the pre-frontal cortex (PFC) of the brain that plays a critical role in working memory (Muller, Machado, & Knight, 2002). When considering the findings of Broglio et al. (2003) and Withnall et al. (2005) on force transfer of protective headbands, an increased transfer of force to the frontal bone and PFC would compromise the integrity

of working memory. The current finding regarding decreased verbal memory scores for the headband group supports this inference from previous research.

The no headband group demonstrated faster reaction times following the heading exercise than the headband group. This finding could be coincidental as the current study is limited to a small sample size and these increases in reaction time are within ImPACT reliable change indices. Moreover, the difference in reaction time reported here, though statistically significant and potentially meaningful in sport performance, represented only a three one-hundredths of a second difference. Further research should be conducted to investigate this finding. However, it should be noted that an improved reaction time supports the idea that heading is not associated with neurocognitive impairment, which is supported by other related studies on soccer heading (Kontos et al., 2011; Matser et al., 1998, 1999, 2001).

A comparison of changes in visual memory, processing speed, reaction time, and total symptoms for the headband group were not significant in the current study. There were also no differences between pre-heading and post-heading ImPACT scores for the no headband group. These results lie in agreement with Guskiewicz et al. (2002) who reported no significant decrease in visual memory, processing speed or reaction time when comparing soccer players to control athletes. The results also support Kontos et al. (2011), who suggested that heading exposure was not associated with neurocognitive impairment or symptoms, and contradict the findings of Matser et al. (1998, 1999, 2001), which supported the inverse relationship between decreases in memory performance and increases in number of headers.

Understanding the possible neurocognitive effects of soccer heading has become an interest of both researchers and clinicians. Since their inception, protective soccer headbands have been purported to reduce the forces to the skull and brain that are associated with head impacts from a soccer ball. Results of the current study question the utility of protective soccer headbands in protecting the athlete from neurocognitive deficits following the heading exercise. Furthermore, the use of protective headbands may have facilitated a greater transfer of force to the participant's head, causing a decrease in neurocognitive function. These results do not support the use of protective headbands as a means to protect players from neurocognitive decrements during repetitive soccer heading.

Limitations

The current study is not without limitations. A small sample size that only included varsity and club soccer players at a single university was used, and recruiting different ages of soccer players would provide a more generalizable soccer population. Another limitation was the speed and distance of the soccer ball, which were just below the average for male and female varsity

collegiate soccer players. Considering the neck strength differences between men and women and the skill differences between club and varsity players, a preliminary study focusing on average kick speeds and distances should be conducted for each sex and skill level. In addition, participants were asked to head each ball from a set distance and speed, which would vary in a competitive setting.

CONCLUSION

Protective soccer headbands did not reduce neurocognitive impairment or symptoms following an acute bout of soccer heading. The current study supported verbal memory impairment following the heading exercise for the headband group, while the no headband group showed a significant improvement in reaction time following the heading exercise. These results may inform sports medicine professionals', parents', and athletes' decisions to utilize soccer headbands as a means to protect soccer players from head injury. Full90 Sports, Inc. focuses the marketing of its protective headbands on reducing injury from head-to-head impacts that occur in soccer, which was not the focus of this study. There is independent evidence that protective headbands reduce force transfer associated with head-to-head impacts (Withnall et al., 2005). The current study questions the effectiveness of soccer headbands in mitigating neurocognitive impairments following an acute bout of repetitive heading and suggests that soccer headbands may exacerbate the acute effects of heading on memory and reaction time. Although it may be beneficial to use protective headbands to guard players from head-to-head impacts, they do not appear to reduce the effects associated with soccer heading.

COMPETING INTERESTS

Dr. Schatz has served as a consultant to ImPACT applications, Inc., in the context of analyzing normative data and establishing age- and gender-based norms. However, ImPACT Applications, Inc. had no role in the conceptualization of the study, the collection or analysis of data, the writing of the article, or the decision to submit it for publication. None of the other authors have conflicts of interest to declare.

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