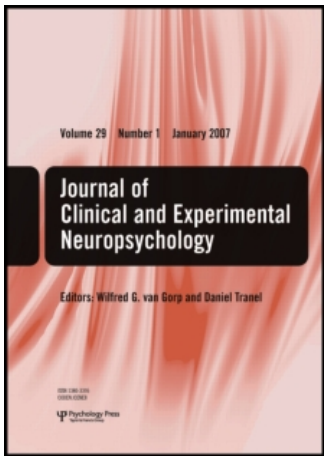

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Thomas W. Kaminski [a]; April M. Wikstrom [b]; Gregory M. Gutierrez [a]; Joseph J. Glutting [c]
[a] Athletic Training Research Laboratory, Department of Health, Nutrition & Exercise Sciences, University of Delaware, Newark, DE, USA
[b] Associated Orthopedic Specialists, Ocala, FL, USA
[c] School of Education, University of Delaware, Newark, DE, USA

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Purposeful heading during a season does not influence cognitive function or balance in female soccer players

Thomas W. Kaminski,[1] April M. Wikstrom,[2] Gregory M. Gutierrez,[1] and Joseph J. Glutting[3]

[1]Athletic Training Research Laboratory, Department of Health, Nutrition & Exercise Sciences, University of Delaware, Newark, DE, USA
[2]Associated Orthopedic Specialists, Ocala, FL, USA
[3]School of Education, University of Delaware, Newark, DE, USA

Soccer participation, especially among females, is growing in popularity in the United States. Purposeful heading, an important soccer skill, has recently been scrutinized for safety reasons. The purpose of this study was to determine whether there was a relationship between purposeful heading and scores on cognitive function and balance in high-school and collegiate female soccer players. Prior to and following the soccer season, all players and members of the control group were given a battery of neuropsychological and balance tests. There were no significant correlations found between the total number of game headers and performance on either balance or neuropsychological testing. Differences were noted in adjusted balance scores postseason between the collegiate players and the other two groups. However, no differences were revealed in neurocognitive performance between the three groups.

INTRODUCTION

Soccer is the most popular team sport in the world. Interestingly, the number of women's world cup teams participating in preliminary competitions more than doubled between 1991 (45 teams) and 2003 (99 teams), evidence of the sport's growing popularity among women worldwide (FIFA, 2005). The popularity of soccer is also growing in the United States (Boden, Kirkendall, & Garrett, 1998), and participation among females in intercollegiate and interscholastic sports has increased significantly since the passing of the Title IX Educational Assistance Act of 1972, which requires federally funded institutions to provide equal opportunity to females in all areas, including athletics. The National Collegiate Athletic Association (NCAA) indicates that participation in women's soccer has increased from 80 schools sponsoring the sport in 1981 to 895 schools sponsoring soccer in 2003, and more women are participating in soccer than in any other NCAA sponsored sport (NCAA, 2004).

The increasing number of soccer players around the world requires that the sport be competitive, yet safe. Sport-related concussion is a form of mild brain trauma, and it has been associated with acute and long-term cognitive and vestibular deficits (Barth et al., 1989; Collins et al., 1999; Tysvaer & Lochen, 1991). If the individual sustains a second concussion before resolution of the first, it can result in impaired playing performance, social degradation, further injury, and possible death (McCrory & Berkovic, 1998). Concussions, in particular, have been shown to result in up to 12.1% of the game injuries in women's soccer, compared to 9.3% in the collision sport of American football (Covassin, Swanik, & Sachs, 2003a). The similarity in injury rate indicates that soccer may be more of a contact/collision sport than is traditionally considered. Recent data from the NCAA reveal an increasing trend in concussions, especially in the sport of women's soccer, with an alarming 46.5% increase in game-related concussion injury rate reported between the 2002 and 2004 seasons

Address correspondence to Thomas W. Kaminski, Dept. of Health, Nutrition & Exercise Sciences, Human Performance Laboratory, 159 Fred Rust Ice Arena, 541 South College Avenue, Newark, DE 19716, USA (E-mail: kaminski@udel.edu).

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(NCAA, 2003, 2005). From 1997 to 2000, concussions accounted for 11% of all game injuries in women's soccer, as compared to just 7% in men's soccer (Covassin, Swanik, & Sachs, 2003b).

Animal models of repeated concussions have demonstrated permanent neuronal (intrinsic) and behavioral (extrinsic) impairments following repeated head injuries (DeFord et al., 2002; DeRoss et al., 2002). This is a model for traumatic brain injury as well as sport-related concussion. Compared to other sports, little is known about the consequences of concussion in soccer (Green & Jordan, 1998). In a study by Tysvaer and Lochen (1991), 54% of active and 70% of former Norwegian soccer players had suffered some type of head trauma during their careers. Matser, Kessels, Jordan, Lezak, and Troost (1998) reported that 79% of the Dutch professional soccer players studied had endured at least one head-to-head collision during their career. In a previous study involving female soccer players, the authors report that 57% had previously sustained a concussion, while 48% of the players had suffered multiple concussive events (Kaminski & Dede, 2002). Collins et al. (1999) found that multiple concussions in American football athletes were associated with long-term cognitive impairments. However, more recent research has called these findings into question indicating that there is not conclusive evidence of the long-term effects of sport-related concussion (Collie, McCrory, & Makdissi, 2006; Iverson, Brooks, Lovell, & Collins, 2006). In any case, research examining the problem of head injuries in soccer worldwide is notably scarce, especially among female players. This is of concern given that the data suggest that an increasing number of soccer players are women.

The relatively high number of head injuries suffered in soccer may be partly due to the nature of the sport. Soccer is unique because its participants purposely use their heads for passing, shooting, and stopping the soccer ball. Even more interesting is the fact that heading has become such a critical aspect of the game, so much so, that many games are won and lost by goals put in by the player striking the ball with their head. Furthermore, the incidental (unintentional) contacts and collisions that occur in the course of a match with other players, the ground, and goal posts provide additional opportunities for head trauma to occur. While the cause of direct trauma to the head via these mechanisms has been widely accepted (Rutherford, Stephens, & Potter, 2003), the incidence of head injuries in soccer from purposeful heading has fueled many debates as to whether or not negative long-term effects exist from this practice.

While the scope of neuropsychological testing is limited in monitoring sport-related concussion, it has become a popular tool to assess neurocognitive function. Meanwhile, assessment of motor deficits postconcussion using postural stability, involving either sophisticated force plate measurement systems or simple clinical balance tests, is an additional instrument that can be used to monitor athletes postconcussion. Guskiewicz (2001) reported postural stability testing to be a useful tool to assess the motor domain of neurological functioning and that these tests could be a reliable and valid adjunct in the assessment of concussions in athletes.

While there is an ongoing effort to examine sport-related concussions in professional, collegiate, and interscholastic collision sports such as football, ice hockey, lacrosse, and boxing, very little, if any, research has been focused on the sport of soccer and in particular women's soccer. The evidence is quite clear that participation in women's soccer is increasing at all levels of competition, and consequently there has been an increase in the number of game- and practice-related concussions. The purpose of this study was to determine whether there was an association between the number of purposeful headers taken in a season and scores on a battery of postural stability and neuropsychological tests in female soccer players.

Our first hypothesis was that there would be a negative relationship between the number of purposeful headers taken in a season and postseason scores on a battery of neuropsychological and postural stability tests in female soccer players. Thus, athletes who head the ball more regularly throughout the season will present with poorer scores on the battery of tests. Additionally, we hypothesized that the collegiate soccer players will exhibit greater differences in their postseason test scores than will a group of control participants and a group of female high-school soccer players. This hypothesis is based on the possibility that continued exposure to purposeful heading throughout an athlete's soccer playing career may influence neurocognitive performance.

METHOD

Participants

A total of 71 female participants ranging in age from 14–24 years old consented to participate in this study. The participant pool consisted of 21 Division I collegiate soccer players, 24 collegiate

TABLE 1
Participant demographics

Group	n	*Age*[a]	*Height*[b]	*Mass*[c]
Collegiate soccer	21	19.1 ± 1.1	167.1 ± 6.8	65.4 ± 5.7
Collegiate controls	24	21.3 ± 1.5	165.4 ± 9.0	60.8 ± 9.3
High school soccer	26	15.1 ± 1.2	164.0 ± 6.4	55.7 ± 5.8

Note. Values shown are mean ± standard deviation.
[a]In years. [b]In cm. [c]In kg.

controls, and 26 junior varsity and varsity high-school soccer players. Members of the collegiate control group were not participating in any organized sport. All participants were free from acute mild brain injury, equilibrium disorders, diagnosed learning disabilities, and recent lower extremity injuries. Participants were also excluded if they suffered a concussion throughout the course of the study. Participant demographic data are presented in Table 1, while positional and experience data are presented in Table 2. Of the 71 participants, 7 of the collegiate players, 2 of the collegiate controls, and 1 of the high school players reported suffering a physician-diagnosed concussion at minimum 6 months prior to the study.

Procedure

All participants were instructed on the methods and the risks involved with participating in the study and subsequently signed an Informed Consent Agreement (Protocol #UFIRB-2000387). If under age 18, a Parental Consent Form was signed by each parent. Participants in the study then filled out a medical questionnaire to insure that they were indeed free from recent injury and generally healthy enough to participate.

Prior to (before any on-field training occurred) and immediately following the soccer season, all participants were given a battery of neuropsychological and postural stability tests in random order. Time between pre- and posttesting ranged from 12 weeks for the high-school group to 14 weeks for the collegiate soccer players and their control counterparts. The modified Romberg Test was used as an indirect measure of postural stability. Participants were asked to stand on their dominant leg (leg used to kick a ball) for 30 s per trial. A 30-s practice trial preceded each test variation, due to the novelty of the test to all of the participants. Each participant performed two trials of each of the four variations of the test in random order. The variations were: (a) eyes open on a firm surface (EOF); (b) eyes closed on a firm surface (ECF); (c) eyes open on the unstable foam surface (EOU); and (d) eyes closed on the unstable foam surface (ECU). A foam Airex® Balance-Pad (Alusuisse Airex AG, Switzerland) was used for the unstable surface variation. The Balance Error Scoring System (BESS) was used as an indirect measure of postural sway (Riemann, Guskiewicz, & Shields, 1999). In short, the test involves using a point system for various errors associated with losing balance during the 30-s timed test. Each trial was scored by the same skilled examiner and was videotaped and reviewed to verify the hand scoring. The total number of errors in all eight trials was recorded and used in the analysis.

The two-part Wechsler Digit Span test (WDST; Psychological Corporation, San Antonio, TX) was used to assess concentration and immediate memory recall. This test required the participant to repeat a series of number strands that increased in length, first in forward order (digits forward) and then in reverse (digits backward). Finally, the Hopkins Verbal Learning Test (HVLT; Brandt, 1991) was administered to assess verbal memory. The participants were to both repeat and recognize words from a list of 12. Six different versions (Forms 1–6) were utilized to prevent redundancy and memorization.

Heading data were documented by counting the number of times that each participant headed the soccer ball during sanctioned games, using a simple tally system. Athletic trainers from the participating schools were responsible for counting the headers and recording them. No attempt was made to distinguish between the types of headers performed.

TABLE 2
Positional and experience data for participants

Group	n	*Forward*	*Defense*	*Midfield*	*Goalkeeper*	*Average playing experience*[a]
Collegiate	21	5	5	9	2	12.3 ± 2.7
High school	26	6	10	7	3	4.3 ± 2.8

[a]In years. Mean ± standard deviation.

Statistical analysis

There were three groups in the study: collegiate players, high-school players, and collegiate controls. The dependent variables included the preseason and postseason measures of postural stability using the BESS scores, the WDST and HVLT scores, and the total number of purposeful headers performed in sanctioned matches. Data were analyzed using a series of analyses of covariance (ANCOVA). Baseline results served as the covariate, and adjusted means from the postseason were the dependent variables. Post hoc comparisons were completed on the adjusted posttest means using the Bonferroni correction. Additionally, a Pearson product moment correlation coefficient was used to analyze the relationship between the total number of purposeful game headers and the difference between the postseason and preseason scores on the battery of tests. Heading data were analyzed with an independent-samples *t* test to determine whether significant differences existed between the collegiate and high-school participants with respect to the number of headers/person/game. The α-level was set at .05, *a priori*. All data were analyzed using the SPSS 13.0 for Windows (SPSS, Inc., Chicago, IL) statistical software package.

RESULTS

Heading data

The number of headers that each athlete executed during every soccer match was recorded (Table 3). Heading data for the collegiate players represents a total of 25 matches, while the data for the high-school players represents a total of 22 matches.

The results of the independent-samples *t* test indicated a significant difference between the two groups, $t(45) = 3.547$, $p = .001$. The collegiate players (2.7 ± 2.3) had a significantly greater number of headers per game than did the high-school players (0.8 ± 1.2).

TABLE 3
Heading data for participants

Group	*n*	*Total game headers*[b]	*Average headers/person/game*[a]
Collegiate soccer	21	1,408	2.7 ± 2.3
High-school soccer	26	420	0.8 ± 1.2

[a]Mean ± standard deviation. Significantly different, $p = .001$.
[b]Includes all the game headers for all the athletes in each group over the entire season.

Correlation analysis

The correlation analysis contained the total number of game headers and the change in preseason to postseason BESS scores for each of the four Romberg test conditions (EOF, EOU, ECF, ECU), as well as the total BESS score and the WDST and HVLT scores. In both the collegiate and high-school groups, there were no significant correlations between the total number of game headers and the change in scores for each of the seven outcome measures. The Pearson product moment correlation coefficients for each analysis are found in Tables 4 and 5.

TABLE 4
Pearson product moment correlation coefficients for the collegiate group

	Total game headers	
Change in score	*Pearson correlation*	*Significance (two-tailed)*
HVLT	−.122	.598
WDST	−.147	.524
BESS: EOF	−.180	.435
BESS: EOU	.268	.239
BESS: ECF	−.323	.153
BESS: ECU	−.363	.106
BESS: total	−.226	.324

Note. $n = 21$. $p \leq .05$. HVLT = Hopkins Verbal Learning Test. WDST = Wechsler Digit Span Test. BESS = Balance Error Scoring System. EOF = eyes open on a firm surface. ECF = eyes closed on a firm surface. EOU = eyes open on the unstable foam surface. ECU = eyes closed on the unstable foam surface.

TABLE 5
Pearson product moment correlation coefficients for the high-school group

	Total game headers	
Change in score	*Pearson correlation*	*Significance (two-tailed)*
HVLT	.158	.442
WDST	−.055	.790
BESS: EOF	.015	.943
BESS: EOU	−.052	.802
BESS: ECF	.035	.864
BESS: ECU	.258	.203
BESS: Total	.139	.498

Note. $n = 26$. $p \leq .05$. HVLT = Hopkins Verbal Learning Test. WDST = Wechsler Digit Span Test. BESS = Balance Error Scoring System. EOF = eyes open on a firm surface. ECF = eyes closed on a firm surface. EOU = eyes open on the unstable foam surface. ECU = eyes closed on the unstable foam surface.

Romberg test scores

BESS scores across all four Romberg test conditions were totaled, and these values were used in all comparisons. Total BESS scores ranged from 17 to 79. A higher score meant that the participants performed worse (more errors) on the test. The results of the ANCOVA indicated a significant main effect for group, $F(2, 67) = 6.911$, $p = .002$ (Figure 1). Pair-wise comparisons revealed that the adjusted collegiate group postseason BESS scores (44.2 ± 9.2) were significantly greater (worse) than both the high-school (34.9 ± 12.2, $p = .024$) and control groups (31.8 ± 10.1, $p = .002$). There was no significant difference in BESS scores between the high-school and control groups ($p = .936$).

Wechsler Digit Span Test scores

Pre- and postseason WDST scores were compared between the three groups. WDST scores ranged from 12 to 24. A higher score on this test is better. The ANCOVA revealed that there were no significant differences between the three groups in adjusted postseason WDST scores, $F(2, 67) = 1.409$, $p = .251$ (Figure 2). The collegiate group presented with slightly, although not significantly, higher (better) adjusted postseason scores (19.4 ± 2.3) than did both the high-school athletes (17.6 ± 3.4) and the collegiate controls (17.4 ± 3.9).

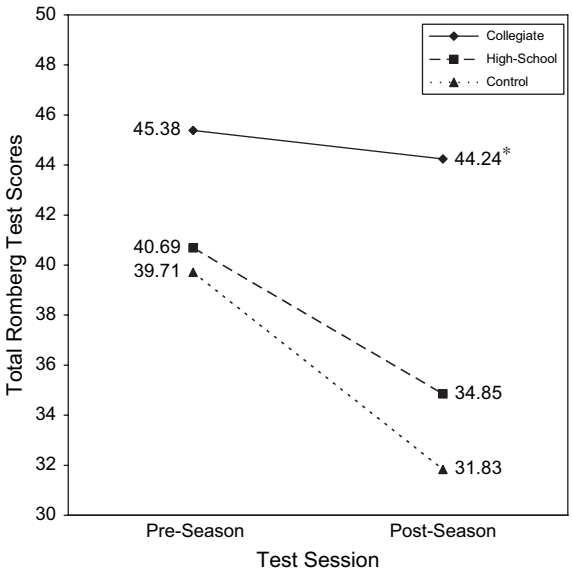

Figure 1. Preseason and postseason Romberg test scores. *Significantly different ($p \leq .05$).

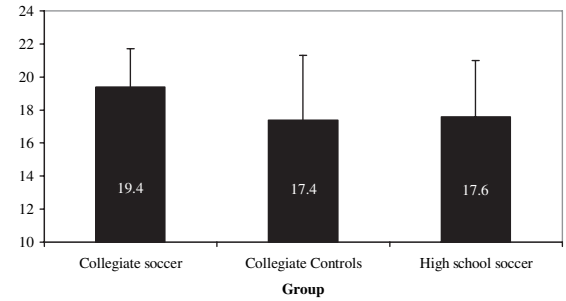

Figure 2. Adjusted postseason Wechsler Digit Span Test (WDST) scores.

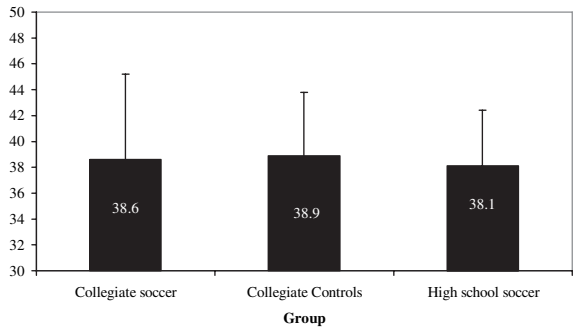

Figure 3. Adjusted postseason Hopkins Verbal Learning Test (HVLT) scores.

Hopkins Verbal Learning Test scores

The pre- and postseason HVLT scores were also compared using a separate ANCOVA. The scores ranged from 30 to 48. Once again, higher scores are interpreted as being better. The ANCOVA revealed that there were no significant differences between the three groups in adjusted postseason HVLT scores, $F(2, 67) = 1.297$, $p = .280$ (Figure 3). All three groups were very similar in terms of adjusted postseason HVLT scores with the collegiate athletes scoring 38.6 ± 6.6, while the high-school athletes scored 38.1 ± 4.3 and the collegiate controls scored 38.9 ± 4.9.

DISCUSSION

The primary goal of this investigation was to determine whether a relationship exists between the number of headers taken in a soccer season and performance on tests of postural stability and cognitive function. Our first hypothesis was that there would be a negative relationship between the number of purposeful headers taken in a season and the change in scores on the battery of neuropsychological and postural stability tests in female soccer players. Thus, athletes who head the

ball more often throughout the season would present with poorer scores on the battery of tests. The results of the current study fail to support this hypothesis. The Pearson product moment correlation coefficient analysis showed no significant correlation between the total number of game headers and the changes in BESS scores for the four Romberg test conditions (EOF, EOU, ECF, ECU), the BESS total, the WDST, or the HVLT.

Our second hypothesis was that the collegiate soccer players would exhibit greater differences in postseason test scores (BESS total, WDST, HVLT) than would both control participants and high-school soccer players. The results of this study failed to support this hypothesis for both the WDST and HVLT scores; therefore, neurocognitive performance does not appear to be affected. However the hypothesis was confirmed when the total BESS scores were compared. The results indicated that adjusted postseason total BESS scores in the collegiate soccer players were significantly higher (worse). It is important to remember that the correlational analysis determined that any changes in cognitive performance were not associated with the total number of game headers. Furthermore, on closer examination of the BESS data for the collegiate group it is evident that their scores were higher (worse) in the preseason assessment (Figure 1), and while the control and high-school groups showed greater improvements (pre- to postseason), the collegiate group remained consistent with their preseason scores.

The main finding of this study was that no significant correlations existed between the total number of game headers per player for a soccer season and the change in scores on the battery of postural stability and neuropsychological tests. These results indicate that female soccer players who head the ball more often do not necessarily perform poorer on tests of postural stability and cognitive function.

The current findings contradict the conclusions from other studies that reported deficits in cognitive function in soccer players compared to that in controls (Matser, Kessels, Lezak, Jordan, & Troost, 1999; Tysvaer, 1992; Tysvaer & Lochen, 1991; Tysvaer & Stroli, 1989). They attributed these deficits to repetitive subconcussive trauma from heading the soccer ball. These studies included participants who were male, had played with a heavier leather ball, abused alcohol, and had suffered acute mild head trauma; all of which may have contributed to their findings. It is possible that a longitudinal study in this area may provide different results. Perhaps data collection during only one soccer season is not sufficient to show any significant deficits. It has been reported that the average velocity of a kick in women's soccer is not high enough to cause a concussion (Levendusky et al., 1988). The collegiate soccer players in our study did not demonstrate cognitive deficits while having on average three times more lifetime exposure to purposeful heading. If neurocognitive insufficiencies develop due to purposeful heading, it is likely that a more significant amount of time is required for deficits to become apparent.

It has been suggested that proper heading technique may protect soccer players from the purported deleterious effects (Tysvaer, 1992). Proper soccer heading involves stabilization of the neck musculature as well as the torso to reduce rotational forces, thus resulting in a greater linear force. A more rotational force, common in boxing, can lead to shearing within the cerebral tissue, thus producing more serious head trauma. It is possible that the participants in the current study executed headers with the correct technique, preventing these shearing forces from affecting the brain and normal brain function. Tysvaer (1992; Tysvaer & Lochen, 1991; Tysvaer & Stroli, 1989) reported that one third of both active and former professional soccer players displayed slightly abnormal to abnormal electroencephalography (EEG) readings. In these studies, players who had described themselves as "typical headers" had fewer abnormal readings than did "nonheaders." "Nonheaders" were soccer players who considered themselves infrequent headers of the ball (Tysvaer, 1992). It was proposed that this was due to the fact that the typical headers used the proper technique.

The Romberg tests may not have been sensitive enough to identify postural stability deficits in the participants of this study. Ingersoll and Armstrong (1992) found that participants who had suffered a severe head injury had greater anterior–posterior and medial–lateral sway than did mild head-injured and noninjured participants. Participants with a mild head injury did not display increased postural sway. It could be inferred that participants without head injury who intentionally head the ball would not exhibit increased postural sway, similar to the participants in the Ingersoll and Armstrong (1992) study who had mild head injuries. It is important to remember, however, that their postural sway data were gathered from a computerized balance system. This posturography system is much more sensitive to changes in sway than are the Romberg test and BESS scoring system used in the present study.

Guskiewicz, Riemann, Perrin, and Nashner (1997) suggested that the WDST and HVLT were not sensitive enough to reveal neuropsychological

deficits in participants with mild head injuries. Their report is based on head injury data involving concussions in athletics. If these tests are not sensitive enough to identify deficits from a mild head injury, they are likely not sensitive enough to pick up deficits that might occur as a result of intentional heading in soccer. Whenever cognitive tests are administered over time, the influence of learning must be addressed. Oliaro, Guskiewicz, and Prentice (1998) determined that there is a learning effect with the WDST, as participant scores significantly improved between each of the three testing days. They reported mean scores for Test Days 1–3 of 17.47, 18.10, and 18.62, respectively. Although a learning effect is possible with these tests, our testing sessions were separated by months instead of hours as was the case in the Oliaro et al. (1998) study, and therefore it is unlikely that a learning effect took place in the present study. The mean pre- and postseason WDST scores for all participants in our study were 18.32 and 18.08, respectively. There was evidence of a possible learning effect only for the high-school group in the present study, as these participants improved from 16.62 to 17.62 from pre- to postseason testing.

Oliaro and colleagues (1998) also established normative data for the HVLT. Their mean scores for Test Days 1–3 were 39.56, 38.64, and 38.61, respectively. The combined mean scores for the participants in our study were 39.04 for the preseason scores and 38.55 for the postseason scores. Again, the high-school participants showed improvement with pre- and postseason test scores of 37.15 and 38.92, respectively. This phenomenon may be further explained by the fact that in the high-school age group, rapid brain growth is occurring, which may have contributed to the improvement in HVLT scores (Daniel et al., 1999).

There were no significant differences between any of the adjusted postseason scores for the HVLT or WDST between the three groups. This finding suggests that the effect of a season, where intentional soccer heading is occurring, does not negatively impact these measures of neuropsychological function.

It is possible that heading the soccer ball simply does not affect balance or cognitive function. A study by Putukian, Echemendia, and Mackin (2000) revealed that there were no acute changes in postural sway following an acute soccer heading bout. Several researchers attribute the deficits reported in previous research to acute head trauma or a combination of acute head trauma and long-term intentional heading (Baroff, 1998; Green & Jordan, 1998; Jordan et al., 1996). The current study excluded participants with a recent history of mild head injury. The deficits reported by Tysvaer (Tysvaer & Lochen, 1991; Tysvaer & Stroli, 1989) and Matser et al. (1999) are intriguing because their exclusion criteria were vague and did not indicate whether or not their participants had suffered from any recent mild head injuries. Interestingly, more recent studies (Broglio, Guskiewicz, Sell, & Lephart, 2004; Magnus, Wallman, & Ledford, 2004; Schmitt, Hertel, Evans, Olmstead, & Putukian, 2004) support the findings of Putukian et al. (2000) that an acute bout of heading has no effect on postural control.

With regard to the adjusted postseason comparisons between the three groups, there was a significant difference in total BESS scores for the collegiate group as compared to the other two groups, while there were no differences between the groups in WDST and HVLT scores. The results indicated that both the control and high-school participants' adjusted postseason total BESS scores from the Romberg tests were significantly lower than those of the collegiate group. The Romberg test is scored using the BESS for assessing points for specified errors; a lower score represents better performance. Therefore, the control and high-school participants performed significantly better overall on the Romberg test than did the collegiate group. Upon further inspection of the data, it becomes clear that while the high-school and control groups were slightly improved from pre- to postseason, the collegiate group did not change (Figure 1). This indicates that one season of soccer participation did not have a detrimental effect on postural control.

It is possible that the high-school participants demonstrated better balance because of a shorter period of soccer participation (collegiate, 12.3 ± 2.7 years vs. high-school, 4.3 ± 2.8 years) and therefore less collective heading over time. It was also evident that the collegiate soccer players averaged significantly more headers per person per game (2.7 ± 2.3) than did the high-school participants (0.8 ± 1.2). The reduced amount of soccer participation combined with a lower heading exposure may have resulted in better postural stability performance in the high-school players than in their collegiate counterparts. Due to these findings it may be wise in future studies to keep these two levels of soccer players separate from each other in any comparative analyses.

Clinical implications

The increasing popularity of soccer among females is evident. Concern over the safety of the sport

necessitates research in this area. Although several injuries are possible from playing soccer, head injuries have attracted attention because of the possible long-term effects (Baroff, 1998; Green & Jordan, 1998; Jordan et al., 1996; Matser et al., 1999; Matser et al., 1998; Riemann & Guskiewicz, 2000). Researchers have reported that there may be negative consequences as a result of the practice of heading the soccer ball (Matser et al., 1999; Tysvaer, 1992; Tysvaer & Lochen, 1991; Tysvaer & Stroli, 1989). However, these studies have been inconclusive because it has been argued that these effects may be due to acute mild head injury as opposed to cumulative trauma (Putukian et al., 2000).

The current study controlled for this by eliminating participants with recent mild head injury or those who sustained a concussion during the study (none of the athletes in this study suffered a concussion during the course of the project). In addition, most research in this area has concentrated on male athletes. The growth of the female soccer population calls for research to include them. Although there was no significant correlation found between heading and the pre- to postseason change in scores on the test battery, some of the results noted in the current study might have been a result of years of heading the soccer ball. Therefore, it is important to be aware of the possibility of these cumulative effects in our clinical practice. The postural stability and neuropsychological tests used in this study are often utilized to assess the effects of a mild head injury. A need for preinjury data on these tests exists because postinjury testing scores often contribute to return-to-play decisions. Without this, clinicians may be unaware that some athletes perform below the norms before any mild head injury occurs.

Limitations/implications for future research

The results of this study suggest a need for future research in the area. It is evident that a longitudinal study is necessary to produce substantial results. Any negative effects of heading the soccer ball are likely not apparent through the course of one season. The length of one soccer season is not sufficient for data collection of this kind. Furthermore, it was clear from working with the soccer teams that a great number of headers are taken in practice drills and scrimmages. The fact that only game headers were counted eliminated some of the intentional (and unintentional) heading that occurs during practice sessions and may account for these findings. Research that includes headers taken in practice and scrimmages may lead to a more complete analysis of the effects of heading.

Furthermore, it is plausible that a few game headers may have been missed due to human error or distractions that occur on the sidelines during the course of a soccer match. It is also possible that the participant population might have influenced this observation. Some of the participants at the high-school level, as well as the control participants, might participate in a wider variety of sporting activities than would those at the collegiate level. Often, elite athletes such as the NCAA Division I collegiate soccer players in this study concentrate solely on their sport and are therefore less likely to participate in other types of sporting activities. Participation or a history of participation, in activities such as cheerleading, gymnastics, and dance may have contributed to better postural stability among the high-school and control participants.

The wider age range and increased number of participants may allow for more reliable results. The testing battery used in the current study may not have been sensitive enough to display deficits. An expanded test battery, with a variety of balance technologies and neuropsychological tests (Trail Making test, Stroop Color–Word test, Symbol Digit Modalities test), or perhaps even one of the commercially available computerized test batteries, will add to the validity of the results.

Summary and conclusions

The increased participation in soccer, especially among females, necessitates a look at the safety of the sport. The high number of head injuries associated with soccer has prompted concern. Data have shown cumulative cognitive deficits in soccer players, suggested to be a result of repetitive heading of the soccer ball. Previous researchers disagree as to whether the negative effects on the brain are due to acute head injury or the purposeful use of the head over time as with soccer heading. The purpose of this study was to determine whether there was a relationship between the total number of purposeful game headers taken in a season and change in scores on a battery of neurological and balance tests in female soccer players. Data analysis demonstrated that there was no correlation between the total number of game headers and the change from pre- to postseason performance on the Romberg test, WDST, and HVLT. The collegiate soccer players demonstrated significantly different adjusted postseason BESS scores of postural stability from those of their control and high-school cohorts. However, neurocognitive function was not affected. It appears as though one season of purposeful heading does not influence cognitive

function or balance in female soccer players; however, future longitudinal research to examine the subject long term is called for.

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