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The Role of Concussion History and Gender in Recovery From Soccer-Related Concussion

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Background: This study was designed to investigate differences in recovery in male and female soccer athletes.

Hypotheses: Soccer players with a history of concussion will perform worse on neurocognitive testing than players without a history of concussion. Furthermore, female athletes will demonstrate poorer performance on neurocognitive testing than male athletes.

Study Design: Cohort study (prognosis): Level of evidence, 2.

Methods: Computer-based neuropsychological testing using reaction time, memory, and visual motor-speed composite scores of the ImPACT test battery was performed postconcussion in soccer players ranging in age from 8 to 24 years (N = 234; 141 females, 93 males). A multivariate analysis of variance was conducted to examine group differences in neurocognitive performance between male and female athletes with and without a history of concussion.

Results: Soccer players with a history of at least 1 previous concussion performed significantly worse on ImPACT than those who had not sustained a prior concussion ($F = 2.92, P = .03$). In addition, female soccer players performed worse on neurocognitive testing ($F = 2.72, P = .05$) and also reported more symptoms ($F = 20.1, P = .00001$) than male soccer players. There was no significant difference in body mass index between male and female players ($F = .04, P = .85$).

Conclusion: A history of concussion and gender may account for significant differences in postconcussive neurocognitive test scores in soccer players and may play a role in determining recovery. These differences do not appear to reflect differences in mass between genders and may be related to other gender-specific factors that deserve further study.

Keywords: concussion; gender; soccer

Between 1 and 4 million sports-related concussions are estimated to occur each year in the United States.¹⁰ Estimates of concussion prevalence have varied historically depending on age, gender, and sport of participation.^{5,18,33} Recent studies have suggested that estimates of diagnosed concussions may represent an underestimate of actual injuries due to the underreporting of concussive symptoms at time of injury.^{17,31} For instance, Delaney

et al¹⁷ found that up to 70% of collegiate football and soccer players experience concussion symptoms during a given season, but only 20% had realized that they had sustained a concussion. Similarly, McCrea et al³¹ found that 66.4% of high school soccer players did not report having a concussion because they were not aware that they needed medical treatment for their symptoms.

There has been a significant increase in research regarding concussion in soccer athletes over the past decade. This is not surprising given that soccer is arguably the most popular sport worldwide, with 240 million amateur players and 200 000 professional players.²⁶ Furthermore, soccer is played by athletes of both genders and all ages and is popular in most cultures worldwide. The most common causes of concussion in soccer include head-to-head contact, head contact with other body parts, and head-to-ground contact.³⁰ Head contact with the soccer ball itself (ie, "heading" the ball) is not considered a risk factor for concussion.³⁰

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Relatively little is known about the effect of history of concussion in soccer players, although this has been studied in other sports.¹³ Delaney et al¹⁷ reported that a history of concussion was associated with sustaining another concussion in both university football and soccer players. Unfortunately, this study used survey data and did not involve the direct cognitive examination of the athletes. Therefore, the data may have been affected by recall bias. In a study that did use neurocognitive testing in a group of nonhelmeted athletes, Collie et al¹¹ found no significant association between number of prior concussions and performance on a cognitive test battery assessing motor function, decision making, attention, learning, and memory in elite Australian Rules football players. Additionally, elite soccer players who presumably have had chronic repetitive heading have not been found to have differences in symptoms or brain MRI findings from athletes with no head contact.²⁵ However, differences in cognitive testing have not yet been thoroughly explored in this group.

In addition to being a universally popular sport, soccer is also a sport that has relatively equivalent participation by both males and females. In fact, soccer had the greatest increase in participation by high school girls during the 2006-2007 school year.³² Soccer is also a sport with identical rules for all participation levels and for both genders.

Recent studies have suggested that female athletes may potentially be at a greater risk for concussion due to differences in head-neck dynamic stabilization.³⁸ It has also been hypothesized that female athletes experience different symptoms after concussion compared with their male counterparts.^{1,19,29,34} If female athletes do indeed experience different symptoms, they may also experience different recovery patterns.^{7,14,16} It is important to identify potential gender-related differences so that appropriate guidelines can be given for the diagnosis and treatment of concussion in female as well as male athletes.

The purpose of this study was 2-fold. First, we examined the effect of prior concussion on postconcussion testing in soccer players. Second, we examined the postconcussion recovery patterns in male and female soccer players who represented a range of competitive levels. We chose to use soccer as it is a nonhelmeted sport with identical rules for all participation levels and for both genders. Our hypotheses were that (1) players with a history of concussion would perform worse on neurocognitive testing than players who did not have a history of concussion and (2) female athletes would demonstrate poorer performance on neurocognitive testing than male athletes, regardless of any potential differences in body mass index (BMI).

MATERIALS AND METHODS

This study was approved by the University of Pittsburgh Institutional Review Board. Athletes selected represented a convenience sample of consecutively treated soccer players who underwent clinical evaluation and neurocognitive testing following the diagnosis of a sports-related concussion. All athletes in our clinical sample were

included, with the exception of athletes with a history of attention deficit disorder or a psychiatric disorder for which they were taking medication. In addition, no athletes were included with a history of seizures or any other known preexisting neurologic disorder.

For this study, concussion was defined as a "traumatically induced alteration in mental status with or without a loss of consciousness," based on the standard American Academy of Neurology nomenclature.²⁷ In addition to alteration of consciousness, athletes were given a diagnosis of concussion if they reported other typical symptoms of injury, such as new headache, dizziness, balance dysfunction, or nausea, after a blow to the head or body. All injuries were diagnosed by a physician or certified athletic trainer who was present at the time of injury. Concussion history was gathered through clinical interview and through completion of the ImPACT (Immediate Post-concussion Assessment and Cognitive Assessment, Pittsburgh, Pennsylvania) concussion-history questions. This series of questions queries the athlete with regard to past blows to the head that involved an alteration/loss of consciousness or loss of playing/practice time after a blow to the head.

The ImPACT test battery evaluates multiple aspects of cognitive functioning and is relatively brief (total time of approximately 25 minutes). The test battery is automatically scored, and produces a 6-page report that is complete with age-referenced percentile scores for select indices. The ImPACT test battery is heavily oriented toward the evaluation of attention, visual scanning, and information processing.

For this particular study, Version 1.0 was used. ImPACT 1.0 yields 3 neurocognitive composite scores: memory, reaction time, and visual motor-processing speed. These 3 measures were used as dependent measures. In addition to the neurocognitive measures, ImPACT also contains a 22-item self-report symptom inventory that queries the athletes regarding their subjective experience of symptoms such as headaches, nausea, dizziness, and memory loss. This inventory is widely used throughout all levels of sport and is included in the Vienna International Concussion Guideline.³

Multiple studies using the ImPACT test battery have indicated that it is both reliable and valid. For example, with regard to reliability, Iverson et al²³ found no significant practice effects in a sample of noninjured high school athletes tested twice within several days. Past validity studies have documented that the ImPACT test battery correlates highly with the Symbol Digit Modalities Test, an often-used test of cognitive speed in research with athletes.²⁴ This test battery has also demonstrated good sensitivity and specificity and is able to discriminate mildly injured athletes from noninjured control subjects.³⁵ ImPACT has also been found to correlate with athletes' self-reports of neurocognitive decline and "fogginess."²²

The administration of the ImPACT test battery was supervised by a team of clinical neuropsychologists, athletic trainers, and/or physicians who were trained in the administration of the standardized inventory.

TABLE 1
Male and Female Soccer Athletes: Demographic, Neurocognitive, and Symptom Raw Scores

	Males N = 93	Females N = 141	F	P Value
Age (y)	16.3 (2.4)	16.5 (2.45)	.75	.39
Education (y)	9.8 (2.3)	10.1 (2.5)	.93	.33
Days after injury	13.3 (12.40)	12.0 (11.80)	.73	.40
	(Median = 9)	(Median = 9)		
Prior concussions, mean (range)	.63 (0-5)	.69 (0-5)	.09	.77
Memory	85.2 (10.1)	83.2 (12.5)	1.2	.28
Reaction time	.57 (.11)	.63 (.17)	8.6	.005
Visual motor processing	37.1 (7.1)	35.0 (9.0)	3.1	.08
Total symptom score	14.0 (2.0)	25.6 (21.2)	20.1	.00001
Body mass index (71 males/106 females)	21.3 (2.3)	21.2 (2.3)	.04	.85

RESULTS

To evaluate the relationship between concussion history, gender, and postinjury neurocognitive performance, a factorial multivariate analysis of variance was completed with the memory, reaction time, and visual processing-speed indices from the ImPACT test battery being entered as the dependent variables; history of concussion (yes or no) and gender (male or female) were the independent variables.

The relationship between gender and neurocognitive functioning after concussion was examined using the ImPACT test battery. The results are presented in Table 1. There was a total of 234 athletes, with 141 females (61%) and 93 males (39%). The groups were not significantly different with respect to the number of previous concussions. The average time of testing after injury was 13.3 days for the male athletes and 12.0 days for the female athletes and the median for both groups was identical (9 days after injury).

The overall multivariate analysis of variance was significant for both concussion history ($F = 2.69, P = .04$) and gender ($F = 2.91, P = .05$). There was no statistically significant interaction between gender and concussion history ($F = 62, P = .60$). Given that overall differences were identified between male and female athletes, follow-up univariate analyses were conducted to evaluate test performance between the male and female athlete groups on specific ImPACT composite scores. Female subjects displayed significantly poorer (slower) reaction time scores than male athletes ($F = 8.6, P = .005$). There was a trend toward poorer performance of the female athletes on the memory and visual motor-processing speed measures, but these differences were not statistically significant.

In an attempt to examine the potential role of BMI with regard to the gender differences in neurocognitive processes, BMI was calculated for a subset of the overall sample ($N = 176$; 106 females, 70 males). Body mass index was calculated by dividing weight in pounds by height in inches squared. This product was then multiplied by 703. The male and female samples had nearly identical BMI values and there was no statistically significant difference between the genders ($F = .04, P = .85$).

To investigate the possible relationship between concussion history and neurocognitive functioning, the soccer

athletes were divided into 2 groups—those with a history of concussion and those without a history of concussion. There were 101 athletes with a history and 133 with no previous concussion. The sample characteristics of these groups are presented in Table 2. There was a statistically significant difference between the groups with regard to age ($F = 10.5, P = .01$) and education ($F = 15.6, P = .001$), with the positive concussion-history group being older and having an average of approximately 1 more year of education. The positive concussion-history group was evaluated an average of 3 days earlier than the no-history group. This difference was not significant ($F = 3.6, P = .06$). The median time of first testing was 7 days for the positive concussion-history group and 11 days for the negative concussion-history group. Therefore, there appears to be a trend in this sample toward the positive concussion group being evaluated somewhat earlier. Follow-up univariate analyses were completed to identify which neurocognitive composite scores differed for the study subjects. Athletes with a reported history of concussion performed significantly worse with regard to memory than did the group who reported no prior concussion ($F = 7.9, P = .005$). The positive concussion group also performed worse on the visual-processing composite score ($F = 4.4, P = .04$). There was a trend toward poorer performance by the positive concussion-history group on reaction time composite, but this difference were not statistically significant.

In addition to the examination of neurocognitive performance, this study also evaluated symptom reporting in the groups of interest. An analysis of variance was also conducted with the total symptom score from ImPACT being used as the dependent variable and concussion history and gender as the independent variables. There was no significant difference between the concussion-history and no-history groups with regard to total symptom score ($F = .30, P = .60$). However, significant differences did emerge between male and female athletes, with female athletes reporting a significantly higher number of total symptoms ($F = 20.1, P = .00001$).

To evaluate whether differences between the concussion history and gender groups were evident when potential preinjury differences (baseline) were accounted for, standardized (T) scores were created for the memory, reaction

TABLE 2
Athletes With and Without a History of Concussion: Demographic, Neurocognitive, and Symptom Raw Scores

	With History N = 101	Without History N = 133	F	P Value
Male/Female	36/65	57/76		
Age (y)	17.0 (2.3)	16.0 (2.4)	10.4	.001
Education (y)	10.7 (2.2)	9.5 (2.3)	15.6	.001
Days after injury	10.9 (12.0) (Median = 7)	13.9 (12.0) (Median = 11)	3.6	.06
Prior concussions				
Memory	85.9 (10.7)	81.5 (12.4)	7.9	.005
Reaction time	0.59 (0.14)	0.63 (0.16)	2.6	.11
Visual motor processing	36.9 (8.5)	34.5 (8.0)	4.4	.04
Total symptom score	20.3 (18.6)	21.8 (22.6)	.30	.60
Body mass index (71 males/106 females)	21.3 (2.2)	21.2 (2.5)	.07	.80

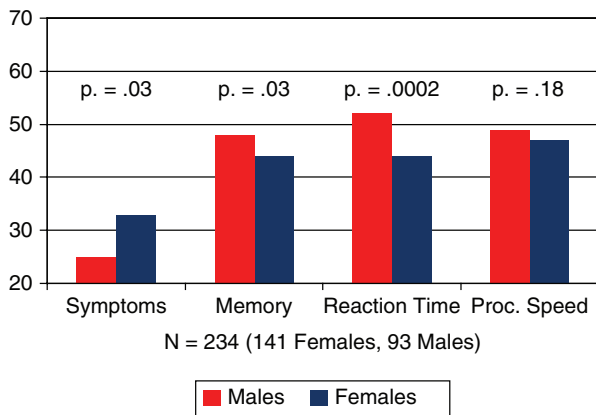


Figure 1. Neurocognitive performance in male versus female athletes' T scores, with mean of 50 and standard deviation of 10.

time, and visual motor-speed indices. Figure 1 provides a visual representation of the magnitude of differences between male and female athletes with and without a history of concussion.

These scores were created by dividing the difference between postinjury neurocognitive test score and the baseline value for each gender. This creates a standard (Z) score with a mean of 0 and a standard deviation of 1. After the creation of the Z score, T scores were calculated by the following formula (10 • Z + 50). The resulting T score has a mean of 50 and a standard deviation of 10. As can be seen in Figure 1, there were significant differences between male and female athletes, even after adjusting for any baseline differences between groups.

Figure 2 presents T scores for the athlete groups with and without a history of concussion. As can be seen from this figure, athletes with and without a history of concussion performed significantly worse on the memory and processing speed when compared with baseline levels.

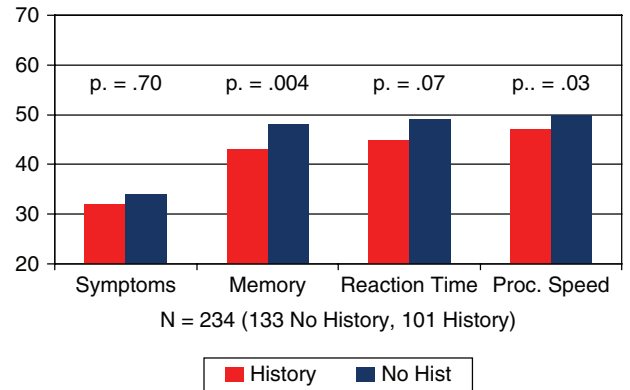


Figure 2. Neurocognitive performance and concussion history scores, with mean of 50 and standard deviation of 10.

DISCUSSION

Despite a sharp increase in research over the past decade, significant uncertainty and controversy continues to exist regarding the management of sports-related concussions. This appears to be at least partially the result of inconsistent definitions of concussion, a lack of knowledge about the underlying pathophysiology of mild concussion, and differing study designs that have yielded conflicting results. The particular sport being studied is also likely to have resulted in differing results. Typically, previous studies that have evaluated the role of concussion history have involved "mixed" groups that consisted of athletes participating in different sports. In our study, we sought to control for potential confounders by using only soccer players.

The results of our study suggest that a history of concussion may be associated with poorer performance in reaction time as measured by a computer-based neurocognitive testing program (ImPACT).

The role of concussion history remains a controversial issue, with previous studies yielding differing results.

Differing results of earlier studies may be due to sport-specific differences or may be dependent on other factors, such as helmet use or nature of the sport (eg, a collision sport like football vs a sport such as soccer where contact occurs but is relatively less frequent). All past samples that have been studied have been composed primarily of male athletes and have been American football and ice hockey players.

Several studies have demonstrated that a history of concussion is associated with sustaining another concussion^{17,36} anywhere from 3 times²⁰ to 5.8 times³⁹ that of an athlete with no concussion history. Furthermore, athletes with a history of multiple concussions have been shown to be more symptomatic and for a longer period of time than athletes with a history of 1 or none.^{9,20}

Although the above-mentioned studies have suggested an increased risk of reinjury after concussion, the implications of a history of multiple concussions on neurocognitive testing is less clear. Several studies have found no significant association between number of prior concussions in Australian Rules and American football players and performance on several different neurocognitive tests.^{6,8,11,21} Contrary to these studies, our study found that soccer players with no history of concussion perform significantly better than those with 1 or more previous concussions on ImPACT testing.

One particularly important difference between the sample used in this study and those from prior studies has to do with the gender makeup of our sample. Unlike earlier studies, this study was composed of a larger group of female (61%) than male athletes. We chose to limit our analysis to soccer players because both genders play without helmets and the sport tends to attract players of similar build. Therefore, we selected the same sport with similar concussion mechanisms to obtain the gender differences. To date, there have been conflicting results as to whether male or female athletes are at a greater risk for concussion. Data from the National Collegiate Athletic Association Injury Surveillance System from 1988 to 2003 demonstrated that concussion was the third most common injury sustained by both male and female athletes during a game.^{2,18} Several authors have also found that female collegiate soccer players are more likely to sustain a concussion than their male counterparts.^{15,17} However, other authors have found that collegiate and Olympic-level female soccer players have relatively equivalent or fewer concussions than male players.^{4,5,33}

This study provides evidence that female soccer players perform worse than male players on neurocognitive testing after a concussion. Although much more research regarding the reasons for this finding is necessary, prior research has demonstrated that female athletes demonstrate different patterns of performance on neurocognitive testing at baseline and after concussion. Covassin et al¹⁴ compared baseline ImPACT scores in collegiate athletes and found that female athletes performed significantly better on verbal memory, while male athletes performed significantly better on visual memory. This difference in visual memory was also reflected in their first postconcussion ImPACT test.¹⁴ Indeed, female athletes manifest different recovery patterns than males.^{7,14,16} Broshek et al⁷ found that female athletes had a significant decrease compared with male

athletes on tests of reaction time and cognitive performance during their first postconcussion evaluation. However, both studies were limited by the mixing of both helmeted and nonhelmeted athletes.

This study also demonstrated that female soccer players report more symptoms than male players after a concussion. The finding of longer-lasting headaches for female athletes may be significant. High school athletes with postconcussive headaches lasting 1 week show greater deficits on neurocognitive tests and experience more general symptoms when compared with concussed athletes without headaches.¹² In addition, women are known to have a higher incidence of headaches than men in the general population³⁷; this may be an important factor with regard to the management of concussion. Finally, it is possible that male and female athletes may report symptoms differently due to factors not related directly to the concussion (eg, psychological or personality factors). However, our finding of greater neurocognitive difficulties in our female athlete sample does not support this hypothesis.

A low BMI (<19.6) has been associated with sustaining a concussion in high school athletes.³⁶ We hypothesized that the effects of a concussion could be potentially greater in a player with a lower BMI; indeed, several authors have focused on the typically stronger male neck and torso in dissipating the force of a head injury.^{17,28,36} However, our study demonstrated that gender appears to be more important than the mass of the player in postconcussive testing.

It is important to note that we used a relatively liberal definition of concussion based on signs and symptoms observed on the field of play. Therefore, athletes who were included may have exhibited a broad range of symptoms, including loss of consciousness, retrograde or anterograde amnesia, a new (hit-related) headache, nausea, visual blurriness, or other symptoms. However, given the many ways that concussion appears clinically, we believe that this sample accurately covers the range of injuries that most sports medicine practitioners are likely to evaluate after injury. There were 2 other limitations to our study. First, the players were not tested the exact same day after injury; however, they were tested at similar times after injury. Second, we did not have preinjury data specific to the players. Instead, we attempted to control for any preexisting differences between groups by comparing test performance to specific normative groups based on both age and gender.

In caring for soccer players, previous concussion history may predict a more long-term cognitive impairment after sports-related concussion. Female soccer players may also have a longer and symptomatic recovery as well. We are hopeful that other researchers will find this area of inquiry important and there will be increased research in this area in the future.

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