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Prevalence of Neurocognitive and Balance Deficits in Collegiate Football Players Without Clinically Diagnosed Concussion

Sports-related concussions have been identified as a major concern for athletes, with an estimated 3.8 million concussions occurring annually.²⁵ A concussion is classified as a mild traumatic brain injury that results from a blow to the head.³⁰ The Centers for



Disease Control and Prevention define a concussion or a mild traumatic brain injury as “a complex pathophysiologi-

cal process affecting the brain, induced by traumatic biomechanical forces secondary to direct or indirect forces to

the head. Disturbance of brain function is related to neurometabolic dysfunction, rather than structural brain injury, and is typically associated with normal structural imaging findings (computed tomography scan or magnetic resonance imaging). Concussion may or may not involve a loss of consciousness. Concussion results in a constellation of physical, cognitive, emotional, and sleep-related symptoms. Recovery is a sequential process and symptoms may last from several minutes to days, weeks, months, or even longer in some cases.²⁶

Concussions have traditionally been diagnosed through a clinical examination performed by a healthcare professional on the sideline at the time of injury.^{2,16,36} Field et al¹³ suggested that clinicians base the diagnosis of a concussion on the following criteria: any observable alteration in mental status or consciousness following a blow to the head or body; the presence of loss of consciousness and/or anterograde or retrograde amnesia; or any self-reported symptoms including headache, fogginess, nausea/vomiting, dizziness, balance problems, or visual problems. However, the diagnosis and subsequent management of concussion continue to evolve to reflect the expand-

- **STUDY DESIGN:** Prospective cohort.
- **OBJECTIVES:** To identify the prevalence of neurocognitive and balance deficits in collegiate football players 48 hours following competition.
- **BACKGROUND:** Neurocognitive testing, balance assessments, and subjective report of symptoms are a test battery commonly used to examine athletes suspected of having sustained a concussion. Previous literature suggests that many concussions go unreported. Little research exists examining the prevalence of neurocognitive or balance deficits in athletes who do not report concussion-like symptoms to a healthcare provider.
- **METHODS:** Forty-five Division IA collegiate football players participated in this study. Pre-season baseline scores using the Balance Error Scoring System, the Immediate Post-Concussion Assessment and Cognitive Testing, and the Postconcussion Symptom Scale were compared to posttest results obtained 48 hours following a game. Prevalence of symptoms was analyzed and reported.
- **RESULTS:** Thirty-two (71%) of the 45 athletes

tested demonstrated at least 1 deficit in either the Postconcussion Symptom Scale, Balance Error Scoring System, or at least 1 composite score of the Immediate Post-Concussion Assessment and Cognitive Testing. Nineteen of the 32 subjects demonstrated a change in 2 or more categories of neurocognitive and balance function.

- **CONCLUSION:** In a cohort of football players tested 48 hours following their last game of the season, who did not seek medical attention related to a concussion, a significant number demonstrated limitations in neurocognitive and balance performance, suggesting that further research may need to be performed to improve recognition of an athlete's deficits and to improve the ability to assess concussion.

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- **KEY WORDS:** BESS, ImPACT, test battery, traumatic brain injury

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ing literature in this area.

When an athlete sustains a concussion, several subjective and objective signs and symptoms may be present, including loss of consciousness, memory loss, mental fogging, sleep disturbances, balance and dizziness complaints, limitations in reaction time, and headaches.^{20,30} These symptoms indicate that the athlete may have a transient injury to the brain with balance or vestibular involvement.^{15,17} This has led to the development of several tests to identify deficits in these areas. Tests such as the Balance Error Scoring System (BESS), the Immediate Post-Concussion Assessment and Cognitive Testing (ImPACT), and the Postconcussion Symptom Scale have been developed to recognize when an athlete has suffered a concussion and to provide objective measurements to assist in determining when an athlete is appropriate for return to play. It is recommended that athletes undergo baseline testing in these areas prior to the season and, if a concussion is suspected, undergo the same battery of tests so that scores may be compared.^{19,33,40} According to Broglio et al,⁴ there is sensitivity of 90% when using the Postconcussion Symptom Scale, neurocognitive testing, and balance testing in combination for the diagnosis of concussion.

Although these guidelines have been suggested, the ability of the test battery to accurately diagnose a concussion could be questioned. Several studies have identified areas that may limit the sensitivity and specificity of this protocol. Van Kampen et al⁴¹ examined high school athletes 2 days following a concussion and compared the results to an age-matched control group. The results identified that 93% of athletes with a diagnosed concussion had either a change in symptom score or abnormalities in neurocognitive testing. In a control group, 30% of the subjects identified a significant change in symptom score or neurocognitive testing.

A study of the effectiveness of the ImPACT to assess for concussion in athletes has reported 89.4% specificity and

81.9% sensitivity.³⁶ The postconcussion checklist, processing speed (reaction time), and visual memory composite are the subsections of the ImPACT with the highest incidence of change exceeding the reliable change index in athletes following a concussion.

The purpose of this study is to evaluate the prevalence of neurocognitive and neurophysiologic deficits present in football players 48 hours following a contest as compared to preseason baseline measurements. It was hypothesized that football players who did not describe symptoms associated with a concussion would have no neurocognitive or balance deficits present.

METHODS

THIS WAS A PROSPECTIVE COHORT study designed to evaluate whether neurocognitive and balance deficits were present in the absence of a clinically diagnosed concussion in football players 48 hours after a game.

Inclusion Criteria

Athletes between the ages of 18 and 25 years, who were on a Division IA collegiate football team and traveled with the team for the final game of the season, were included in the study.

Exclusion Criteria

Athletes who met the following criteria were excluded from the study: those who sustained a concussion during the season in which the data were collected, were not on the traveling team, reported signs and symptoms associated with a concussion and were evaluated at the time of the game or prior to data collection, and were currently being treated for a lower extremity musculoskeletal injury.

Subjects

Forty-six collegiate football players were identified for participation in the study. One player sustained a musculoskeletal injury and was excluded. Forty-five subjects (mean \pm SD age, 19.56 \pm 1.16

years; height, 182.6 \pm 5.51 cm; body mass, 101.75 \pm 20.82 kg) were recruited from the available convenience sample of athletes who dressed for the final game of the season. Prior to participation, all procedures were explained to each subject and informed consent was obtained. The Institutional Review Board at Saint Francis University approved the study protocol, and the rights of the subjects were protected throughout the study.

Procedures

Three examiners performed data collection for this study. Prior to collecting the data for this study, the examiners met for a session to review and operationally define the procedures to be used. The assessment tools selected for this study were chosen given their wide use in clinical practice, as well as being recommended by organizations such as the National Collegiate Athletic Association.^{18,35} Data collection took place at the DiSepio Institute for Rural Health and Wellness on the campus at Saint Francis University.

Baseline testing was conducted prior to the start of the football season in a classroom setting, between the hours of 1:00 PM and 4:00 PM. The testing session lasted approximately 40 minutes. Subjects completed the ImPACT (Version 2.1), including the Postconcussion Symptom Scale, in a supervised classroom on a campus computer. After completing the test, they moved to a second classroom where they completed the BESS testing.

Players included in the study participated in data collection approximately 48 hours following the conclusion of the last game of an 11-game season. This was to remain consistent with the written protocol for concussion management in place at the university where testing was performed. Data were collected between the hours of 1:00 PM and 4:00 PM to remain consistent with the procedures used for baseline testing. Data collection included completion of a questionnaire about the position played, approximate number of plays the athlete participated in, and whether the athlete recalled sustaining a

TABLE 1

SUBJECT DEMOGRAPHICS*

	All Subjects (n = 45)	Subjects With Positive Findings in the Test Battery (n = 32)	Subjects With No Findings in the Test Battery (n = 13)	Difference Between Groups With Positive Findings and Without Positive Findings
Age, y	19.56 ± 1.16	19.50 ± 1.23	19.65 ± 1.05	P = .673
Height, cm	182.60 ± 2.16	181.90 ± 5.76	184.20 ± 4.59	P = .166
Weight, kg	101.75 ± 20.82	99.49 ± 19.36	108.43 ± 23.07	P = .233
BMI, kg/m ²	30.41 ± 5.23	30.18 ± 5.80	30.78 ± 5.80	P = .727

Abbreviation: BMI, body mass index.

*Values are mean ± SD, unless indicated otherwise.

hit to the head. The subjects then completed the ImpACT and the BESS in the same fashion as described in the pretest session. Both testing sessions were administered and/or proctored by the physical therapy staff at the DiSepio Center for Rehabilitation. The players were administered the ImpACT on a campus computer and completed the following subsections: verbal memory, visual memory, processing speed, reaction time, and the self-report.

Measures

The BESS is a clinical test designed to assess postural stability on stable and unstable surfaces in 3 different stance positions.³⁴ Each of the 3 positions under the 2 conditions is held for 20 seconds, while the evaluator counts the number of times the athlete deviates from the proper stance position (number of errors). The maximum number of errors that can be recorded for each condition is 10, with a total maximum BESS score of 60. A change of 3 or greater from baseline testing is considered the minimal detectable change (70% confidence interval), and the athlete is considered to have a change in balance.^{22,40} Although the BESS is a widely accepted clinical test, it has demonstrated limited interrater and intrarater reliability.¹⁴

The Postconcussion Symptom Scale is a subjective report of an athlete's description of limitations or complaints. Typically, the athlete is asked to rate the severity

of 22 symptoms associated with a concussion. Each symptom is graded on a Likert scale (0 to 6, with 0 as no symptoms and 6 as severe symptoms). Responses to the scale are tallied and recorded, for a total possible score ranging from 0 to 132. This scale has been included in the ImpACT program and was administered prior to the neurocognitive testing component. A change of 10 points from baseline has been identified as the minimal detectable change.²⁴ Although the Postconcussion Symptom Scale has been shown to correlate with an athlete's neurocognitive deficits when an athlete is initially injured,^{7,9} it does not appear to identify when neurocognitive signs return to baseline, due to the fact that neurocognitive deficits are often present after self-reported symptoms subside.^{3,12}

ImpACT is a computer-based neurocognitive test that measures a variety of cognitive areas to determine whether the athlete has limitations in attention, processing of information, memory, and reaction times.^{8,9,26} The ImpACT test provides a score in 4 composite areas: verbal memory, visual memory, reaction time, and visual motor speed. The verbal and visual memory composite scores range from 0 to 100, expressed as a percentage of correct responses. The visual motor speed composite score can range from 0 to 60. The reaction-time composite is a time-based score based on time required to produce correct responses.²⁷ Published normative data exist for each component

of the ImpACT test. Iverson et al²⁴ determined the reliable change index for each component of the test as follows: verbal memory, 6.83 points; visual memory, 10.59 points; reaction time, 0.05 seconds; visual motor speed, 3.89 points.

Data Analysis

Statistical analysis included descriptive statistics of the subjects in the study. For each measure used in this study, prevalence of scores exceeding reliable change from baseline was reported, as well as the number of positive findings each subject displayed. Prevalence was also reported based on the position the subject played.

RESULTS

DEMOGRAPHIC DATA FOR THE SUBJECTS included in the study are summarized in TABLE 1. TABLE 2 presents the pretest and posttest mean scores and standard deviations for the testing instruments used in the study. Testing identified that 32 (71.1%) of the 45 athletes demonstrated at least 1 measure that exceeded reliable change in the Postconcussion Symptom Scale or the BESS, or at least 1 composite score of the ImpACT test. Thirteen (40.6%) of the 32 subjects exceeded reliable change in only 1 of the screening tools used or 1 category on the ImpACT tool. Nineteen (59.4%) of the 32 exceeded reliable change in at least 2 of the 3 screening tools used or had at least 2 subcategories that exceeded the reliable change index during the ImpACT.

FIGURE 1 identifies the number of categories in which subjects exceeded reliable change on the ImpACT test. Of the 28 subjects who displayed a score exceeding reliable change, 21 (75.0%) had only 1 category that exceeded reliable change, whereas 7 subjects (25.0%) demonstrated change in 2 or more categories. When examining the results of the ImpACT test by category (composite score), the visual memory composite demonstrated the highest incidence of change, as demonstrated by 11 subjects (39.3%). Ten subjects (35.7%) demonstrated a change in

TABLE 2

PRETEST AND POSTTEST GROUP MEAN SCORES FOR TESTING INSTRUMENTS*

	All Subjects (n = 45)	Symptomatic Group (n = 32)	Nonsymptomatic Group (n = 13)
BESS test			
Pretest	7.33 ± 4.53	6.77 ± 4.35	8.91 ± 5.03
Posttest	8.71 ± 4.40	9.25 ± 4.10	7.38 ± 4.98
ImPACT memory composite (verbal)			
Pretest	84.00 ± 11.29	83.44 ± 11.76	85.38 ± 10.34
Posttest	85.38 ± 11.80	83.66 ± 12.80	89.31 ± 8.04
ImPACT memory composite (visual)			
Pretest	74.36 ± 12.13	75.41 ± 11.19	71.77 ± 14.34
Posttest	75.82 ± 13.74	74.31 ± 14.67	79.54 ± 10.74
ImPACT visual motor speed			
Pretest	41.79 ± 7.63	42.65 ± 7.15	39.69 ± 8.64
Posttest	40.16 ± 10.09	38.86 ± 10.86	43.33 ± 7.13
ImPACT reaction time			
Pretest	0.55 ± 0.10	0.53 ± 0.05	0.59 ± 0.16
Posttest	0.57 ± 0.10	0.58 ± 0.11	0.55 ± 0.08
Total symptom score			
Pretest	2.29 ± 4.94	1.81 ± 3.11	3.46 ± 7.91
Posttest	3.69 ± 5.87	4.47 ± 6.53	1.76 ± 3.30

*Abbreviations: BESS, Balance Error Scoring System; ImPACT, Immediate Post-Concussion Assessment and Cognitive Testing.
Values are mean ± SD.

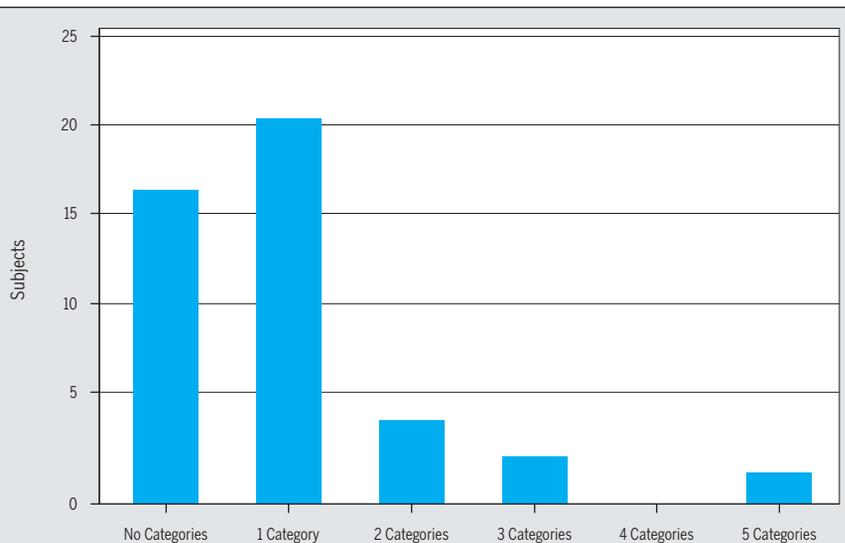


FIGURE 1. Number of categories that exceeded the reliable change index on ImPACT 48 hours following competition. Abbreviation: ImPACT, Immediate Post-Concussion Assessment and Cognitive Testing.

reaction time, 7 (25.0%) demonstrated deficits in visual motor speed, and 4 subjects (14.3%) demonstrated deficits in verbal memory.

Nineteen (42.2%) of 45 subjects demonstrated an increase from baseline greater than 3 points while performing the BESS, exceeding reliable change.

Four subjects (8.9%) demonstrated an increase in the Postconcussion Symptom Scale of 10 or greater, exceeding reliable change.

FIGURE 2 identifies the position played and how many subjects demonstrated neurocognitive and balance deficits versus those with no deficits noted. It should be noted that 5 (15.6%) of the subjects who demonstrated neurocognitive and/or balance deficits did not play in the final game.

DISCUSSION

EXAMINATION AND TREATMENT OF concussions have evolved over the past few years, with identification of guidelines and specific tests available to assist the clinician in providing more objectivity in the diagnosis and management of these injuries.^{19,28,30,37} This study examined athletes 48 hours following a football game. None of the athletes tested in this study reported having symptoms, nor did they seek medical treatment following the game. The results of the present study suggest that when using a multifaceted assessment in the asymptomatic athlete, 71.1% of those tested had neurocognitive impairments and/or balance deficits that may be associated with concussion.

Despite the recent developments and improvements in the diagnosis and treatment of concussion, a significant number of concussions go unreported.²⁹ Given the prevalence of unreported concussions, a significant number of athletes may be participating in practice or competition with a present or previous concussion, putting them at risk for further injury. Although a battery of tests are available and used by healthcare providers, assessment for concussion is limited solely to those athletes who report or overtly display signs and symptoms of concussion, such as a headache, fogginess, loss of balance, etc. Another limitation to testing is that the symptoms associated with concussion may present several hours following the concussion, and, therefore, the athlete

may not correlate these symptoms with the injury that occurred during practice or competition.²¹ The athlete also may be unaware that the signs and symptoms may be indicative of a potential concussion. Either of these situations may prevent an athlete from seeking the care of a healthcare provider. This is concerning, given the relationship to the cumulative damage that may occur to the brain over time when injuries are not recognized.³¹

When further examining the results of this study, it is important to consider the potential for false positive findings with concussion-testing procedures, which have been reported in the literature to range from 10% to 30%.^{36,41} Thirteen (40.6%) of the 32 subjects demonstrated a change from baseline testing to post-testing in only 1 category (either the BESS or 1 of the subsections of the ImPACT). None of these subjects demonstrated an increase in the Postconcussion Symptom Scale. Further research is needed to determine if subjects in this category were demonstrating deficits associated with concussion or if the findings were incidental and could be classified as false positive, as previously described.^{36,41} The identification of false positive findings was beyond the scope of this study.

Furthermore, the results identified that 19 (59.4%) of the 32 subjects demonstrated at least 2 deficits in the test battery or more than 1 of the subcategories of the ImPACT that exceeded the reliable change index. This may be of importance, given evidence that the greater the number of changes present in the subcategories, the higher the likelihood of neurophysiologic and balance changes.^{4,24,41} Specifically, Iverson et al²⁴ indicated that athletes with concussion are 47 times more likely to have 2 or more declines on the ImPACT and/or Postconcussion Symptom Scale than nonconcussed athletes. Although having 2 more declines on the ImPACT does not guarantee that an athlete has sustained a concussion, this finding suggests that neurocognitive deficits associated with concussion might have been present in

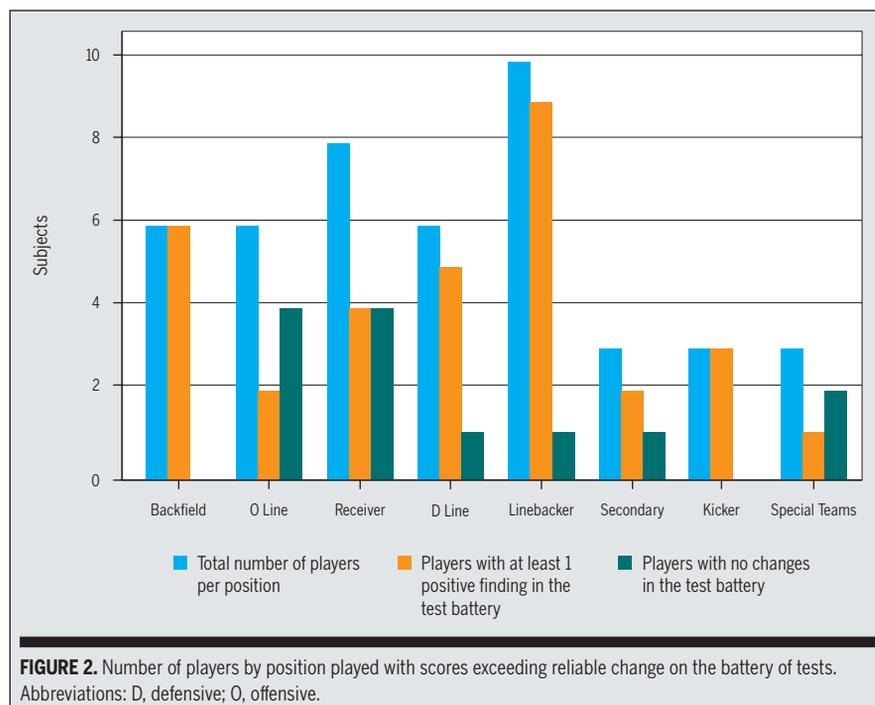


FIGURE 2. Number of players by position played with scores exceeding reliable change on the battery of tests. Abbreviations: D, defensive; O, offensive.

these athletes.

The findings of this study suggest that a moderate number of subjects have a neurocognitive or balance change following a football game in which they did not report sustaining a concussion or blow to the head. However, one cannot conclude that these deficits were specifically related to the final game of the season. Emerging literature suggests that deficits may be attributed to cumulative effects of a season or to the presence of musculoskeletal injury.^{23,39} Further testing would need to be completed to fully assess these subjects to identify potential deficits and potential causative factors.

Linebackers demonstrated the highest incidence of neurocognitive/balance changes when the data were examined by position. This is important to note, given that previous research has identified linebackers as displaying the highest incidence of concussions per exposure.²¹

This study examined the prevalence of abnormal findings in a small population, and it was hypothesized that there would be no changes in neurocognitive or balance performance following a game as compared to preseason baseline testing.

Previous research found that there were no significant neurocognitive changes in collegiate football players throughout a football season.³² The current study seems to contradict previous results and suggests that there may be a change in neurocognitive and balance performance following a football game or as a result of the repetitive contact that occurs throughout a season. The difference in findings may be attributed to the fact that the previous study³² collected post-season data within 2 weeks of the final game of the season, whereas the current study collected data within 48 hours of the final game.

When examining the results of the study, several additional findings are presented. First, the subjective report of symptoms has been identified as one of the key components of concussion assessment and correlates with neurocognitive and balance deficits.^{3,7,8,10} None of the subjects identified any symptoms (headache, fogginess, dizziness, etc) when verbally asked. Interestingly, 4 of the 45 subjects (8.9%) reported symptoms while completing the symptom scale component of the ImPACT test, with a total

symptom score change that exceeded the reliable change index as compared to the baseline measurement. The results of this study call into question the ability to use a postconcussion scale or subjective report to effectively rule out a concussion.

There are several possible reasons why subjects did not identify subjective symptoms when objective findings of neurocognitive or balance deficits were present. The questions verbally posed to the subject might not have been asked in a manner that would have elicited a response as effectively as the symptom scale. The subjects might not have correlated their symptoms with an injury. The deficits might have been so subtle that the subjects did not perceive that a problem existed or did not want to report their symptoms to the investigator. When subjects were asked to grade their symptoms, however, they were more likely to give a more accurate response.

Broglio et al³ reported that 38% of athletes diagnosed with a concussion by a physician still demonstrated neurocognitive deficits when reporting symptom resolution. The results of the current study appear to be consistent with previous research indicating a limitation in correlating symptom score and neurocognitive and balance deficits. The findings of this study suggest that neurocognitive deficits may be present in a large portion of athletes participating in football.

When all 3 clinical tests that made up the test battery (Postconcussion Symptom Scale, composite scores on ImPACT testing, and BESS) were used, some interesting findings were noted. Thirty-two of the subjects who used the test battery displayed deficits that would be considered a significant change. Fifteen subjects demonstrated deficits in 1 test, 15 demonstrated deficits in 2 tests, and 2 demonstrated deficits in all 3 tests. These findings are noteworthy for a number of reasons. First, given the reported sensitivity of the test battery, these findings suggest that a number of the athletes tested demonstrated signs associated with the diagnosis of concussion. Second,

had any of these subjects complained of symptoms to a healthcare provider, they would have been further assessed for a concussion and likely held out of practice or competition until the deficits returned to baseline. Furthermore, these findings suggest that a large number of athletes participating in football who claim to be asymptomatic may have deficits present.

In the present study, testing using the BESS revealed that 18 (40.0%) of the 45 subjects assessed demonstrated a significant change, defined as an increase in 3 or more points from the baseline measure. Four of the subjects only demonstrated limitations in balance. Although the athletes tested demonstrated a change in balance as defined by the test parameters, one could question these results and suggest that this number could be higher. One reason for this may be that, though the BESS assesses an athlete's balance and static vestibular function, it is limited in assessing dynamic vestibular function. A recent study identified prolonged recovery in patients who had vestibular dysfunction following a concussion.¹ Although these questions related to balance and vestibular function in the concussed athlete remain unanswered and warrant further research, they were not the purpose of this study. This study attempted to follow the procedure that would be used given the current standard of practice in concussion management.

There are several limitations of the current study. First, given that this is a convenience sample, the results have limited generalizability to the greater population. Although significant findings were noted, this study needs to be replicated with a larger sample to validate the findings. Second, because this study examined subjects who were asymptomatic, results are limited to athletes who have not reported symptoms associated with a concussion to medical personnel. These results identify the need for research to develop additional tests and measures, especially in the balance and vestibular arena. Third, the study did not control for the activity of the subjects for the 48

hours between the end of the game and the time of testing. This is important, because the literature has identified that alertness at the time of testing, intensity of exercise, and sport may have an effect on testing.^{5,11} Although the authors attempted to have testing performed at a similar time and under similar testing conditions, none of the variables were controlled for and need to be acknowledged as such. Fourth, our study did not utilize a control group, which might have limited the significance of the findings. However, numerous previous studies have identified that age-matched controls in the athletic population have not exhibited signs associated with concussion or have exhibited far fewer signs than athletes who have suffered a concussion.^{24,36,41}

The results of this study appear to mirror findings recently reported by Talavage et al.³⁸ Talavage et al³⁸ identified a group of high school-aged athletes who exhibited significant changes in neurocognitive function and neurophysiologic performance in the absence of clinically observed symptoms associated with concussion. This may be a trend emerging in the literature, which suggests that symptoms in the neurophysiologic, neurocognitive, and balance systems may be overlooked when subjective symptoms are not present.

CONCLUSION

THE RESULTS OF THE PRESENT STUDY demonstrate that, although asymptomatic, a significant number of football players had limitations in neurocognitive function and balance scores 48 hours after the last game of the season. These findings suggest the need for further research in this area to improve recognition of an athlete's deficits. Although reported symptoms are one of the more important ways to identify an athlete who has sustained a concussion, there appear to be limitations in relying on these findings alone, as they may not be sensitive enough to rule out a concus-

sion. The results of this study suggest that further assessments should be performed to identify those athletes who may have deficits but who do not recognize or report them to medical professionals. ●

KEY POINTS

FINDINGS: In the absence of a clinically diagnosed concussion, a significant number of football players had deficits in neurocognitive function and balance scores 48 hours following a game.

IMPLICATIONS: Although reported symptoms are one of the more important ways to identify when an athlete has sustained a concussion, there appear to be limitations in relying on these findings alone, as they are not sensitive enough to rule out a concussion. The results of this study suggest that further assessments should be performed to identify those athletes who may have deficits but who do not recognize or report them to medical professionals.

CAUTION: This study was conducted on athletes from a single football team and thus may have limited ability to be generalized to the greater population of collegiate-level athletes. This study needs to be replicated with a larger sample to validate the findings reported.

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