Which On-Field Signs/Symptoms Predict Protracted Recovery From Sport-Related Concussion Among High School Football Players?

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Background: There has been increasing attention and understanding of sport-related concussions. Recent studies show that neurocognitive testing and symptom clusters may predict protracted recovery in concussed athletes. On-field signs and symptoms have not been examined empirically as possible predictors of protracted recovery.

Purpose: This study was undertaken to determine which on-field signs and symptoms were predictive of a protracted (>21 days) versus rapid (<7 days) recovery after a sports-related concussion. On-field signs and symptoms included confusion, loss of consciousness, posttraumatic amnesia, retrograde amnesia, imbalance, dizziness, visual problems, personality changes, fatigue, sensitivity to light/noise, numbness, and vomiting.

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

Methods: The sample included 107 male high school football athletes who completed computerized neurocognitive testing within an average 2.4 days after injury, and who were followed until returned to play as determined by neuropsychologists using international clinical concussion management guidelines. Athletes were then grouped into rapid (<7 days, n = 62) or protracted (>21 days, n = 36) recovery time groups. The presence of on-field signs and symptoms was determined at the time of injury by trained sports medicine professionals (ie, ATC [certified athletic trainer], team physician). A series of odds ratios with χ² analyses and subsequent logistic regression were used to determine which on-field signs and symptoms were associated with an increased risk for a protracted recovery.

Results: Dizziness at the time of injury was associated with a 6.34 odds ratio (95% confidence interval = 1.34-29.91, χ² = 5.44, P = .02) of a protracted recovery from concussion. Surprisingly, the remaining on-field signs and symptoms were not associated with an increased risk of protracted recovery in the current study.

Conclusion: Assessment of on-field dizziness may help identify high school athletes at risk for a protracted recovery. Such information will improve prognostic information and allow clinicians to manage and treat concussion more effectively in these at-risk athletes.

Keywords: concussion; mild traumatic brain injury (mTBI); signs/symptoms; neurocognitive testing; recovery time; prognosis

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appropriate return to the classroom. Moreover, concrete information on predictors and risk factors for protracted recovery after a concussion may assist in developing focused treatments to expedite recovery time. Several factors, including poorer performance on neurocognitive reaction time and visual memory and the presence of migraine/somatic (eg, headache, dizziness) cluster symptoms subacutely (2-3 days after injury), have been reported as potential predictors of a protracted recovery.\textsuperscript{15,22,23} Surprisingly, on-field signs and symptoms at the time of injury have not been studied as possible predictors of prognosis (ie, recovery time) after a sports-related concussion.

On-Field Signs and Symptoms

On-field signs and symptoms have been used by researchers to identify high school and collegiate athletes with poorer presentation at initial follow-up.\textsuperscript{6} Patients were placed into 2 groups based on presentation at follow-up within 5 days of injury as good or poor presentation. Poor presentation was defined as a decline in memory of 10 or more points on computerized neuropsychological tests along with at least a 10-point increase on the Post-Concussion Symptom Scale (PCSS). Analysis revealed that athletes with poor presentation at 2 to 3 days after injury were 10 times more likely to experience retrograde amnesia and 4 times more likely to experience posttraumatic amnesia (PTA).\textsuperscript{6} The researchers, however, did not examine the effects of on-field signs and symptoms on athletes’ recovery times after concussion.

Traditionally, on-field loss of consciousness (LOC) played a major role in the on-field assessment and management of concussion\textsuperscript{24-31}; however, researchers have questioned its importance in the diagnosis and prognosis of concussion.\textsuperscript{12,34,36} As such, researchers turned to other measures such as retrograde amnesia and PTA to assess concussion.\textsuperscript{6} Researchers reported that the presence of both retrograde amnesia and PTA was useful in diagnosing concussion.\textsuperscript{6} More recently, researchers have focused on imbalance and dizziness in relation to concussion outcomes.\textsuperscript{12,34,36,38}

Traditionally, balance involves the interplay of 3 distinct central nervous systems: visual, proprioceptive (somatosensory), and vestibular.\textsuperscript{29} Impairment in any 1 of these systems may lead to imbalance. Balance is typically assessed by clinicians using practical, observational rating tests such as Romberg test,\textsuperscript{21} tandem walking, and heel-to-toe testing and the Balance Error Scoring System (BESS)\textsuperscript{,28} or Clinical Tests of Sensory Interaction and Balance (CTSIB).\textsuperscript{5} Balance can also be measured using more accurate, but less practical, biomechanics assessments involving accelerometers, force plates, and video analyses.\textsuperscript{12,34} In contrast, dizziness is a self-reported symptom that may involve vertigo (ie, illusion of movement), presyncopeal lightheadedness (ie, feeling of impending faint), or psychophysiologic symptoms (eg, space phobia).\textsuperscript{29} Researchers utilizing the BESS and biomechanical force-plate testing report that imbalance after a concussion resolves within 3 to 7 days after injury.\textsuperscript{12,24,36} A study of mild traumatic brain injury (mTBI) identified dizziness along with headache as the most common and persistent complaints after injury.\textsuperscript{42} In summary, several on-field signs and symptoms are present during the diagnosis and recovery from a concussion (eg, LOC, retrograde amnesia, PTA, balance, and dizziness) but their effectiveness as markers of protracted recovery from a sport-related concussion have yet to be examined.

Purpose of the Study

The purpose of this study was to examine, using a series of univariate nonparametric tests (ie, $\chi^2$ with odds ratios (ORs)), which on-field signs and symptoms were associated with an increased risk of a protracted recovery after a sport-related concussion in high school athletes. The factors associated with protracted recovery identified in these initial analyses were then examined using a subsequent logistic regression (LR) to determine which among the factors were most predictive of protracted recovery. The on-field signs and symptoms included the following: confusion, headache, LOC, PTA, retrograde amnesia, imbalance, dizziness, visual problems, personality changes, fatigue, sensitivity to light/noise, numbness, and vomiting. On the basis of previous research,\textsuperscript{6} we hypothesized that the presence of on-field retrograde amnesia, PTA, and dizziness\textsuperscript{42} would predict protracted recovery from concussion. Recent reports that the presence of LOC has a limited role in concussion\textsuperscript{26} and recovery of balance typically occurs within 3 to 7 days\textsuperscript{12,34,36} led us to hypothesize that LOC and imbalance would not predict protracted recovery from concussion.

METHODS

Design

The study involved a 5-year prospective cohort design. The independent variables were on-field signs and symptoms including confusion, headache, LOC, PTA, retrograde amnesia, balance problems, dizziness, visual problems, personality changes, fatigue, sensitivity to light/noise, numbness, and vomiting. The dependent variable was recovery time to return to play (RTP).

Participants

The participants consisted of male high school football players from the state of Pennsylvania who incurred a sport-related concussion during the preseason or regular season between 2002 and 2006. All athletes participated in the Pennsylvania Interscholastic Athletic Association, which strictly enforces all their rules regarding the number of preseason practices, scrimmages, and games each team may undertake every season. Preseason games begin 2 weeks before regular season play and 1 scrimmage is permitted at the end of each preseason week. During the preseason, each team typically has 3 practices per day. Teams are allowed 3 contact practices per week during the regular
season. All teams play a total of 9 regular season games (11 total games in preseason and regular season). This study only included athletes who had suffered concussions during preseason and regular season football activity, practices, and games and did not include athletes who were injured in postseason playoffs. Under agreement with each school’s athletic trainer, all athletes regardless of perceived severity were referred to the sports concussion program and not permitted to RTP unless cleared by specialists.

The players ranged in age from 13 to 19 years with an average age of 16.02 years (standard deviation [SD] = 1.22 years). Inclusion criteria for the study were: (1) diagnosed concussion by trained medical personnel (ie, athletic trainers, team physician); (2) documented, observed on-field signs and symptoms by trained sports medicine staff at the time of injury; and (3) evaluation and follow-up by clinical members of the research team until RTP. Exclusion criteria included current or history of the following: (1) brain surgery, (2) substance abuse, or (3) other neurologic disorder (seizures, meningitis, psychiatric diagnosis, alcohol abuse). Additionally, patients were excluded from the sample if they were not cleared to RTP, lost to follow-up, or did not return to football before the end of data collection (the end of 2006 regular season).

During the course of the study, 176 athletes suffered concussions and were consented and followed. A total of 69 athletes did not RTP, were lost to follow-up, or did not return to football before end of data collection and were excluded. Unfortunately, the individual reason for this level of exclusion was not recorded. Among the remaining 107 potential participants, a total of 62 athletes met criteria for rapid (≤7 days) and 36 for protracted (>21 days) recovery, for a total sample of 98. Nine participants fell between 7 and 21 days. A summary of participant characteristics is presented in Table 1.

### Measures

**Concussion.** A concussion was defined as a complex pathophysiologic process affecting the brain, induced by direct or indirect traumatic biomechanical forces. In practice, athletes were diagnosed with a concussion by a member of the team’s sports medicine staff (ie, athletic trainer, team physician) who was present at the time of injury. The basis for initial diagnosis of concussion was on-field presentation of 1 or more of the following signs and symptoms after a direct or indirect impact to the head: (1) confusion, (2) headache, (3) LOC, (4) PTA, (5) retrograde amnesia, (6) balance problems, (7) dizziness, (8) visual problems, (9) personality changes, (10) fatigue, (11) sensitivity to light/noise, (12) numbnness, and (13) vomiting.

**On-Field Signs and Symptoms.** On-field signs and symptoms of concussion were observed and recorded at the time of injury by members of the sports medicine staff (ie, athletic trainer, team physician). Before the study, the researchers trained the sports medicine staffs of each participating institution to identify the presence of the on-field signs and symptoms described above. Balance was tested through Romberg, tandem walking, and heel-to-toe testing. Dizziness was assessed through direct questioning and self-report by the athlete.

**Neurocognitive Performance and Symptom Reports.** The Immediate Post-concussion Assessment and Cognitive Test (ImPACT), which includes the 22-item PCSS, was used to assess postinjury neurocognitive performance on 4 composite scores (verbal and visual memory, motor processing speed, and reaction time) and total concussion symptoms and to inform subsequent RTP decisions. The validity and reliability of the ImPACT test have been reported.

**Determination of Recovery Time and RTP.** Recovery time was defined as the period between day of injury and clearance to RTP. Return to play was determined by resolution of symptoms and return of preinjury cognitive function under the care of clinical neuropsychologists who specialize in sport-related concussion using established international consensus protocols. After RTP was determined, neuropsychologists communicated findings to team personnel, athletic trainers, physicians, and coaches.

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1. References 16-18, 22, 25, 27, 33, 35, 37, 41.

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### Table 1

<table>
<thead>
<tr>
<th></th>
<th>Total Sample (N = 107)</th>
<th>Rapid Recovery (≤7 Days, N = 62)</th>
<th>Protracted Recovery (≥21 Days, N = 36)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean age, y</td>
<td>16.02 (SD = 1.22)</td>
<td>16.01 (SD = 1.27)</td>
<td>15.83 (SD = 1.38)</td>
</tr>
<tr>
<td>Mean days to recovery</td>
<td>13.26 (SD = 9.05)</td>
<td>4.31 (SD = 1.74)</td>
<td>29.61 (SD = 6.65)</td>
</tr>
<tr>
<td>Mean days evaluation</td>
<td>2.24 (SD = 1.93)</td>
<td>2.11 (SD = 1.46)</td>
<td>2.94 (SD = 2.88)</td>
</tr>
<tr>
<td>Previous concussion</td>
<td>29 (27.1%)</td>
<td>16 (25.8%)</td>
<td>11 (30.56%)</td>
</tr>
<tr>
<td>History of headache</td>
<td>11 (10.3%)</td>
<td>5 (8.06%)</td>
<td>6 (16.67%)</td>
</tr>
<tr>
<td>History of migraine</td>
<td>11 (10.3%)</td>
<td>3 (4.84%)</td>
<td>3 (8.33%)</td>
</tr>
<tr>
<td>History of ADHD</td>
<td>4 (3.74%)</td>
<td>0 (0%)</td>
<td>3 (8.33%)</td>
</tr>
<tr>
<td>History of any learning disorder</td>
<td>2 (1.87%)</td>
<td>2 (3.23%)</td>
<td>0 (0%)</td>
</tr>
</tbody>
</table>
Participants were returned to play (ie, recovered) when they met the following 4 criteria:

1. Athletes had to be asymptomatic at both rest and after exertion protocols. Graded exertional protocol requires athletes to be symptom-free at rest and with progressively more strenuous activity (ie, walking, jogging, wind sprints). All physical exertion was monitored by sports medicine staff, and athletes were not returned to play until they were evaluated by clinical staff and met the RTP criteria at both rest and after physical exertion.

2. The athlete’s total score on the PCSS was less than 7. The 22 symptoms within the PCSS are not specific to concussion, and athletes may report symptoms at the time of baseline. Iversen et al. reported that the mean PCSS score for noninjured high school males was 5.8 despite never having suffered a concussion and that 76% scored 6 or less, with a large portion scoring 0 (40.5%). Therefore a threshold of 7 was used for this study. Regardless of their PCSS score, no athlete was returned to play if they were experiencing any symptoms or dysfunction that was attributable to their injury.

3. The athlete must not have had 2 ImPACT neurocognitive composite scores that were statistically lower (ie, reliable change estimate) than their baseline performance or age-normative data. The study by Iversen et al. showed that uninjured athletes with 1 neurocognitive composite score below baseline were not uncommon, but only 3.6% of uninjured athletes had 2 scores below baseline. Reliable change estimates were based on Iversen’s observations for significance at 80% confidence intervals: 9 points for verbal memory composite, 14 points for visual memory composite, 0.06 seconds for the reaction time composite, and 3 points for the processing speed composite.

4. Lastly, all of the athlete’s neurocognitive composite scores must have been above the tenth percentile for his age, which broadly represents the normal range. The only exception was if a patient’s baseline before was below the tenth percentile. It is important to note that the majority (84%) of the total sample completed baseline neurocognitive testing, with 79.31% and 83.87% of the rapid and protracted groups, respectively. If baseline testing was not available, participants were compared with published age-matched normative data.

Based on the above criteria, athletes were grouped into rapid (≤7 days, n = 58) or protracted recovery (≥21 days, n = 31) groups. The mean recovery time in days for the rapid and protracted groups was 4.31 (SD = 1.74) and 29.61 (SD = 6.65) after correction for outliers, respectively.

Procedures

The university’s Institutional Research Board approved the current study’s protocol. The researchers then obtained written informed parental consent and participant assent from the participants. During the course of the study, concussed athletes were identified by members of each team’s sports medicine staff. The sports medicine staff also assessed and recorded the presence of the on-field signs and symptoms at the time of injury. Concussed athletes were then referred to a team of clinical neuropsychologists specializing in sport-related concussion management. All athletes at participating schools during the time frame of this study were referred to concussion specialists from a single group throughout recovery regardless of perceived “severity.” All athletes required clearance from the team of clinical neuropsychologists based on the recovery criteria discussed earlier to RTP. After clearance to RTP, decisions were communicated to team personnel to use this information. Thus, players were highly motivated to follow up. Participants completed the postconcussion ImPACT test and symptom report on average 2.4 days (SD = 2.12) after an injury. The rapid and protracted recovery were tested on average 2.11 (SD = 1.46) and 2.94 (SD = 2.88) days after injury, respectively. Athletes were deemed “recovered” when they met all RTP guidelines as described above. After RTP, athletes were grouped into rapid (≤7 days) and protracted (≥21 days) recovery based on time from injury until clearance to RTP. Although this method did not include the full range of recovery times, we chose to use 7 days and 21 days because we believed it would provide a clearer picture of specific predictors of the extremes of recovery.

Statistical Analysis

Descriptive data were used to describe the prevalence of each sign and symptom at time of injury. Fisher exact tests were conducted to assess differences between rapid and protracted recovery groups on potential confounding variables including preinjury history of migraine, headache, attention deficit disorder/attention deficit hyperactivity disorder (ADD/ADHD), learning disorder, and at least 1 sign or symptom was LOC, with only 13.3% (n = 13) reporting this symptom. A summary of total frequencies and frequencies for the protracted and rapid recovery groups for each sign and symptom is provided in Table 2.

The results of the Fisher exact test indicate no significant differences between protracted and rapid recovery
Dizziness as an Onfield Predictor of Protracted Recovery. The significance of dizziness as a sign or symptom of concussion has been reported previously by researchers. In 1 study, researchers reported a 17.5% prevalence of dizziness during emergency room evaluation among mTBI patients. A similarly designed study also showed that days) recovery in concussed high school football student-athletes followed until full recovery and RTP. Return to play was defined as resolution of symptoms under international graded exertional protocol and return of cognitive functioning with ImPACT testing. The findings in the current study indicated that on-field dizziness was associated with an OR of $6.34$ increased risk of a protracted recovery. It should be noted that mean days to recovery for rapid and protracted groups were 4.31 and 29.61, respectively. The remainder of the on-field signs and symptoms (confusion, LOC, PTA, retrograde amnesia, imbalance, visual problems, personality changes, sensitivity to light/noise, numbness, or vomiting) were not significant predictors of protracted recovery in the current study. Given the current findings, the role of dizziness in prognosis for concussion is discussed in the following sections.

**DISCUSSION**

Summary of Results

The current study explored on-field signs and symptoms as predictors for a protracted ($\geq 21$ days) versus a rapid ($\leq 7$ days) recovery in concussed high school football student-athletes followed until full recovery and RTP. Return to play was defined as resolution of symptoms under international graded exertional protocol and return of cognitive functioning with ImPACT testing. The findings in the current study indicated that on-field dizziness was associated with an OR of $6.34$ increased risk of a protracted recovery. It should be noted that mean days to recovery for rapid and protracted groups were 4.31 and 29.61, respectively. The remainder of the on-field signs and symptoms (confusion, LOC, PTA, retrograde amnesia, imbalance, visual problems, personality changes, sensitivity to light/noise, numbness, or vomiting) were not significant predictors of protracted recovery in the current study. Given the current findings, the role of dizziness in prognosis for concussion is discussed in the following sections.
Dizziness adversely affected Glasgow Outcome Scale-Extended (GOS-E; a measure of patients’ social activities and family relationships) at 1, 2, 4, and 8 weeks after mTBI. Chamelian and Feinstein4 reported that dizziness in adults (mean age, 33.6 years) was an independent predictor of failure to return to work at 6 months after mTBI. The finding in the current study lends further support to the importance of dizziness as a predictor of recovery time and may be the first to do so in sport-related concussion. In addition, the prevalence of dizziness in the current study was higher than previously reported with 81.3% (n = 87) of all concussed high school athletes, and 94.4% (n = 34) of the protracted recovery group reporting on-field dizziness.

**Dizziness Versus Balance.** Dizziness and balance are often linked together as subjective and objective impairments of similar nervous system functioning, respectively. The result of the current study, however, suggested that dizziness and balance did not predict recovery in a similar fashion. In fact, dizziness was the only significant risk factor for protracted recovery (OR = 6.34; P = .02), whereas balance was not a significant risk factor. This finding highlights the importance of assessing dizziness separately from balance at the time of injury to inform prognostic outcomes after concussion.

As mentioned earlier, dizziness can be the result of multiple organic reasons including disturbances in vestibular (ie, vertigo), visual, or cardiovascular (ie, syncope) systems.29 The athletes in the current study did not complete objective balance, vestibular, visual, or cardiovascular testing at the time of injury. As such, the role of these individual systems in the dizziness reported by the participants in the current study is unknown. Moreover, the subjectively reported imbalance in the current study may not reflect the results obtained if objective balance assessments were used. On-field objective tests that directly assess dizziness and the involved components of each system are warranted to determine the cause of dizziness after concussion.

At present there is no consensus measure of dizziness. Dizziness is typically measured using postural/balance testing, self-report dizziness questionnaires, or both.29 The finding in the current study suggested that only dizziness, and not imbalance, was a risk factor for protracted recovery. As such, we believe that postural/balance testing and dizziness tests should be looked at individually. It is important to indicate that postural/balance testing should not be used as a proxy for dizziness. Instead, clinicians and researchers should use questionnaires that assess dizziness including the University of California Los Angeles Dizziness Questionnaire (UCLA-DQ),13 Dizziness Handicap Inventory (DHI),19 and Dizziness Beliefs Scale (DBS)43 may be appropriate.29 Each of these measures has been validated to measure dizziness frequency, intensity, and effect on daily activities and quality of life; self-perceived dizziness-associated disability and handicap; and its ability to predict the degree of handicap for patients with dizziness, respectively.13,15,19,20,43,44 Such measures would augment postconclusion assessment in addition to neurocognitive tests, symptom reports, and postural/balance tests. Additionally, follow-up vestibular assessments should be used to further delineate the cause of dizziness and inform subsequent therapy and treatment of this symptom. Finally, a recent finding found that patients who had at least 2 rehabilitation visits for persistent dizziness after a concussion showed improvement in their DHI scores.1 It is possible that on-field identification of dizziness may lead to earlier implementation of vestibular rehabilitation and other modalities to treat dizziness, which may expedite recovery from concussion.

**Imbalance, Amnesia, and LOC.** The finding of the current study suggested that imbalance as determined by Romberg, tandem walking, and heel-to-toe testing was not predictive of protracted recovery. This finding is analogous to those reported in recent studies of imbalance after concussion. Researchers utilizing the BESS with concurrent biomechanical force-plate testing reported that imbalance after a concussion resolved within 3 to 7 days after injury.12,34,36 Similarly, in the current study retrograde amnesia and PTA were also not predictive of protracted recovery from concussion. A possible explanation why imbalance and amnesia were not predictive of protracted recovery is that such deficits may be part of the normal acute response to a concussion and resolve relatively quickly with little lasting effects. It is important to note that in the current study, LOC was not a significant predictor of protracted recovery from concussion. A possible explanation for this finding is that LOC may represent the brain’s defensive mechanism to prevent detrimental or lasting consequences by reducing energy demands and brain function at time of injury. Regardless of the underlying reason, in the current study brief LOC had limited utility as an on-field sign/symptom. It is important to note that the current sample did not include athletes with prolonged (>1 minute) LOC. Therefore, the current findings should not be applied to prolonged LOC at time of injury.

**Limitations**

The current study was limited by several factors. The sample comprised only male high school football players. Therefore, the results cannot be generalized to other athletes, females, or other sports. Although the history of previous concussions were recorded and shown not to be significant between groups, it is possible that these numbers may underrepresent the actual number of athletes with a previous concussion. As such, in this study a history of previous concussion may have an unseen effect on recovery. On-field predictors were assessed and reported by sports medicine staff using brief screening tests and questions with potentially concussed athletes on the sidelines. As such, report bias and other errors in such measures might have affected the results. In this study, participants were assessed for balance using Romberg, tandem walking, and heel-to-toe tests. Postural/balance tests specific for sports-related concussion such as the BESS were not used. The BESS test may be more effective for use with the current population. Further details of sport-specific balance tests may be referenced in a review by Guskiewicz.11 This was a homogeneous sample of athletes who
Conclusion and Future Research

The results of the current study support 2 distinct findings. First, the results indicated that the presence of on-field dizziness was a robust predictor for protracted recovery in sport-related concussions. Second, the results suggested that other on-field signs and symptoms were not significant predictors of protracted recovery from concussion. The latter finding should be interpreted cautiously as previous research has supported retrograde amnesia and PTA as predictors of poor concussion outcomes (although not protracted recovery times, per se). Moreover, sensitive balance testing (eg, BESS, CTSIB) for sport-related concussion was not used in this study, and therefore the findings regarding imbalance must also be interpreted cautiously. Nonetheless, if additional, prospective studies confirm our finding that dizziness may indicate protracted recovery, it would indicate the need for direct assessment of dizziness at time of injury to inform both prognosis and potential therapies to enhance recovery. As such, we believe that clinicians and researchers should consider using separate, specific tests for dizziness (eg, DHI), in addition to traditional postural/balance tests (eg, BESS, CTSIB) in future studies, rather than relying on postural/balance tests as indicators of dizziness.

REFERENCES


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