Injuries In Sports Essay, Research Paper

Relationship Between Concussion and

Neuropsychological Performance in College

Football Players

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Context Despite the high prevalence and potentially serious

outcomes associated with concussion in athletes, there is little

systematic research examining risk factors and short- and long-term

outcomes.

Objectives To assess the relationship between concussion history

and learning disability (LD) and the association of these variables with

neuropsychological performance and to evaluate postconcussion

recovery in a sample of college football players.

Design, Setting, and Participants A total of 393 athletes from 4

university football programs across the United States received

preseason baseline evaluations between May 1997 and February

1999. Subjects who had subsequent football-related acute

concussions (n=16) underwent neuropsychological comparison with

matched control athletes from within the sample (n=10).

Main Outcome Measures Clinical interview, 8 neuropsychological

measures, and concussion symptom scale ratings at baseline and

after concussion.

Results Of the 393 players, 129 (34%) had experienced 1 previous

concussion and 79 (20%) had experienced 2 or more concussions.

Multivariate analysis of variance yielded significant main effects for

both LD (P\*.001) and concussion history (P=.009), resulting in

lowered baseline neuropsychological performance. A significant

interaction was found between LD and history of multiple concussions

and LD on 2 neuropsychological measures (Trail-Making Test, Form

B [P=.007] and Symbol Digit Modalities Test [P=.009]), indicating

poorer performance for the group with LD and multiple concussions

compared with other groups. A discriminant function analysis using

neuropsychological testing of athletes 24 hours after acute in-season

concussion compared with controls resulted in an overall 89.5%

correct classification rate.

Conclusions Our study suggests that neuropsychological

assessment is a useful indicator of cognitive functioning in athletes

and that both history of multiple concussions and LD are associated

with reduced cognitive performance. These variables may be

detrimentally synergistic and should receive further study.

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The management of mild traumatic brain injury (MTBI; eg,

concussion, defined as a traumatically induced alteration in mental

status not necessarily resulting in loss of consciousness) in athletics

is currently one of the most compelling challenges in sports

medicine. Despite the high prevalence1 and potentially serious

outcomes2, 3 associated with concussion, systematic research on

this topic is lacking. Many sports medicine practitioners are not

satisfied with current return-to-play and treatment options, which do

not appear to be evidence based.4-6 There is also little research

examining whether long-term cognitive morbidity is associated with

concussion. Past research with nonathletes revealed that repeated

concussions appear to impart cumulative damage, resulting in

increasing severity and duration with a second MTBI occurring within

48 hours.7 No data were presented which addressed more long-term

outcomes.

Although survey data have shown that a prior history of head injury

increases the risk for sustaining subsequent MTBI,8 other potential

risk factors associated with sports-related concussion have not been

identified. Learning disability (LD), the etiology of which is presumably

secondary to central nervous system dysfunction,9 refers to a

heterogeneous group of disorders manifested by difficulties in the

acquisition and use of listening, speaking, writing, reading, reasoning,

or mathematical abilities and which is traditionally diagnosed in early

childhood.10, 11 The incidence of diagnosed LD is 11.8% in the

general university population.12 However, no study to date has

addressed whether LD may represent a risk factor (such as that seen

with prior head injury) for poor outcome following sports-related MTBI

in college athletes.

Previous research has outlined the reliability, validity, and sensitivity

of neuropsychological tests in assessing the specific cognitive areas

associated with MTBI in the general population.13-15 To date, 3

published studies have examined the use of neuropsychological

testing in US football players.16-18 The only multicenter study16 was

conducted in the mid-1980s and was designed to address the acute

effects of concussion.

The current study was designed to address 2 issues: first, to

investigate whether a relationship exists between prior concussion

and diagnosed LD among college football players and determine the

influence of these variables, in isolation and combination, on baseline

neuropsychological performance; and second, to evaluate the use of a

neuropsychological test battery in diagnosing concussion and

delineating recovery of cognitive function following MTBI in athletes.

METHODS

Subjects

Participants in this study consisted of 393 male college football

players from 4 Division IA football programs: Michigan State

University, East Lansing (n=119); the University of Florida, Gainesville

(n=106); the University of Pittsburgh, Pittsburgh, Pa (n=85); and the

University of Utah, Salt Lake City (n=83).

At the initial preseason baseline session, the following self-reported

data were collected: age, playing position, SAT/ACT scores

(Scholastic Aptitude Test/American College Testing, ie, college

entrance examination scores), history of LD, neurological history (eg,

central nervous system neoplasm or epilepsy), history of psychiatric

illness (eg, depression and/or mania or anxiety), history of alcohol

and/or drug abuse, prior sports played, and history of concussion.

Educational records at each institution were used to verify a

documented history of diagnosed LD. A standardized concussion

history form was administered at baseline to obtain detailed

information regarding previous concussions, year of concussion,

description of incident, nature and duration of relevant symptoms (eg,

confusion and/or disorientation, retrograde and/or anterograde

amnesia, and loss of consciousness), neuroimaging results (if any),

and days lost from participation in football (if any). Athletes who

reported amnesia were asked to provide any known collateral

information from the athletic trainer, sports-medicine physician, or

other source familiar with the details of the incident. All previous

concussions were classified using the practice parameter of the

American Academy of Neurology.19

Protocol and Outcome Measures

Preseason Baseline Evaluation

Appropriate review for research with human subjects was granted

separately from the 4 institutions at which the participants were

enrolled. Each participant provided written informed consent for

voluntary participation. All data collection was completed by the

research team of clinical neuropsychologists (clinicians with PhDs or

doctoral-level students) or team physicians or athletic trainers who

were thoroughly trained in the use of the measures. Each examiner

was required to attend a 2-hour workshop and was supervised during

test adminstration (by M.W.C.) to facilitate the appropriate

standardized administration of the test battery. All measures were

administered and scored in a standardized manner to minimize

differences between test administrators and institutions. Project

investigators trained in neuropsychological assessment completed all

data scoring and interpretation.

Baseline data collection at 3 universities (Michigan State University,

University of Pittsburgh, and University of Florida) was completed prior

to the 1997/98 and 1998/99 football seasons during the months of

May to August. Baseline data collection at the University of Utah

occurred during February 1999 for the 1999/2000 season (only

baseline data from the University of Utah were used for analyses).

Approximately 95% of all roster football players (scholarship and

scout team players) voluntarily participated in the project. At these

baseline sessions, demographic and player history information was

obtained via interview.

Each athlete was then administered a battery of neuropsychological

tests (approximately 30 minutes in length) that is used by the

National Football League.17, 20 Tests in the battery were the Hopkins

Verbal Learning Test (HVLT; verbal learning, delayed memory);

Trail-Making Tests, Forms A and B (Trails A and Trails B; visual

scanning and executive functioning); Digit Span Test (attention and

concentration); Symbol Digit Modalities Test (SDMT; information

processing speed); Grooved Pegboard Test, dominant and

nondominant hand (bilateral fine motor speed); and the Controlled

Oral Word Association Test (COWAT; word fluency). This test

battery, described in detail elsewhere,17 was constructed to evaluate

multiple aspects of cognitive functioning. In addition to

neuropsychological testing, athletes also completed the Concussion

Symptom Scale17 to assess a baseline level of self-reported

symptoms. This Likert scale consists of 20 symptoms commonly

associated with concussion (eg, headache, dizziness, and trouble

falling asleep), with symptoms ranging from none (score, 0) to severe

(score, 6).

Postconcussion Evaluation

Athletes who sustained a concussion during the course of a season

underwent serial neuropsychological evaluations following the incident

(within 24 hours of the incident, and at days 3, 5, and 7 postinjury).

Concussion was defined according to the American Academy of

Neurology practice parameter.19 Thus, players experiencing a

traumatically induced alteration in mental status, not necessarily

resulting in a loss of consciousness, were included. Athletic trainers

initially identified the majority of suspected concussions, and

respective team physicians performed the examinations and made

the final decisions. Once the diagnosis was established,

neuropsychological testing was administered as soon as possible

following injury (within 24 hours in all cases). The neuropsychological

tests and self-report inventory used in the postinjury phase were

identical to those used at baseline, although alternate and reliable

forms of the HVLT and COWAT were administered to minimize

learning effects associated with these measures.

Football players from within the sample served as controls. Control

athletes were matched with athletes who sustained concussion

according to ACT/SAT scores, history of LD, history of previous

concussion, institution, and playing position. In addition, to control for

exertion, each control athlete was tested within the same time frame

as the athletes who experienced concussion (eg, following a game or

practice). Within the context of these variables, it was possible for

controls to be matched to more than 1 player with concussion. No

control athlete experienced a concussion during the course of the

study. Controls were excluded from further study.

Data Analysis

Data from the 4 universities were pooled and analyzed using

Statistica Version 5.1 statistical software for Windows.23 To explore

the relationship between prior history of concussion, diagnosis of LD,

and neuropsychological baseline performance, multiple analysis of

variance (MANOVA) was performed. Concussion history (no prior

concussion vs 1 vs 2 concussions) and LD (positive or negative

diagnosis) were entered as independent variables, and cognitive and

symptom total scores were entered as dependent measures. The

MANOVA design was selected to allow an analysis of performance

differences between the athletes with different concussion and LD

histories, across multiple neuropsychological domains. This design

also permitted an analysis of possible interaction effects between

concussion and LD histories.

For in-season (postconcussion) data, a discriminant function

classification analysis was conducted to determine the accuracy of

the neuropsychological test battery in separating athletes with

concussions from control athletes within 24 hours of concussion. The

8 tests constituting the neuropsychological test battery were used as

predictor variables, and membership in the group with concussions or

control group was used as the dependent (grouping) variable.

To provide preliminary information regarding the recovery pattern of

athletes with concussions relative to the control group and to their

own baseline performance, standard scores were created to convert

the selected neuropsychological test scores to a common metric.

These standard scores were constructed so that baseline

performance for each group would have a mean of 100 and SD of

15.21 Group differences of one-half SD (7.5 standard score units) are

considered to reflect at least a moderate difference between the

means.22 Any deviation from 100 indicates a change in performance

relative to baseline for each group. The recovery pattern of players

who sustained concussion across different time intervals was

evaluated by standardizing all neuropsychological test results and

comparing performance of the athletes with concussion with controls’

performance within 24 hours, and at 3, 5, and 7 days postinjury.

RESULTS

Demographic Data and Concussion History

The multiuniversity sample included 393 male football players with a

mean (SD) age of 20.4 (1.7) years and 2.6 (1.3) mean (SD) years in

college. Forty-six percent of the sample was African American, 48%

European American, 4% Polynesian American, 1% Asian American,

and 1% Hispanic American. Of the 393 players, 6% (n=25) were

quarterbacks; 8% (n=33), running backs; 13% (n=52), wide receivers;

16% (n=64), offensive linemen; 6% (n=23), tight ends; 17% (n=67),

defensive backs; 16% (n=61), defensive linemen; 13% (n=48),

linebackers; and 5% (n=20), kickers.

Of the players completing the ACT examination to qualify for college

admission (n=180), the mean (SD) score was 20.0 (1.7). Of those

qualifying with the SAT (n=200), the mean (SD) score was 952.9

(149.1). College admission scores were missing for 13 individuals.

Three players in the sample reported a documented history of

diagnosed psychiatric illness (eg, bipolar disorder and major

depression). These players completed the baseline evaluation, but

were excluded from further study. No player in the sample reported a

diagnosis of major neurological disorder or history of abuse of alcohol

or other drugs.

Forty-six percent (n=179) of the sample reported no prior history of

concussion, 34% (n=129) reported experiencing 1 concussion of any

grade, and 20% (n=79) reported a history of 2 or more sustained

concussions (range, 2-10) of any grade. A significant relationship was

found between total years participating in football and total number of

concussions sustained (r=0.15; P.02). Quarterbacks (17 of 25) and

tight ends (15 of 23) had the the highest rates of prior concussion

(68% and 65%, respectively). Running backs-fullbacks (11 of 33) and

kickers-punters experienced the lowest rates of prior concussion

(33% and 46%, respectively).

The prevalence of LD within the total sample of 393 athletes was

13.5% (n=53). Of the players with no history of concussion (n=179),

10.6% (n=19) had a diagnosed LD; of those who had experienced 1

prior concussion (n=129), 14.7% (n=19) had diagnosed LD, and of

those who had experienced multiple concussions (n=79), 19.0%

(n=15) had a diagnosed LD. Although these data suggest a possible

trend between history of LD and history of multiple concussions, this

relationship was not statistically significant (2=3.74; P=.15).

Previous Concussions, LD History, and Baseline

Neuropsychological Performance

The MANOVA yielded significant main effects for both LD (F=4.57;

P\*.001) and concussion history (F=1.91; P=.009) on

neuropsychological test results, which indicated that both of these

variables were significantly related to overall neuropsychological

performance. The interaction of LD and concussion history was not

significant (F=1.17; P=.28). A follow-up series of univariate F tests

was completed to identify the specific neuropsychological measures

that accounted for the significant MANOVA. Tests for the LD main

effect were Trails B (F=15.98;P\*.001); SDMT (F=22.9; P\*.001);

COWAT (F=11.6; P\*.001); and Hopkins delayed memory (F=11.8;

P\*.001). For the history of concussion main effect, significant tests

included Trails B (F=6.1; P=.002); SDMT (F=7.8; P\*.001); and total

symptoms reported (F=4.6; P=.01).

To evaluate concussion group differences on the neuropsychological

tests, additional post hoc analyses were conducted using the Tukey

Honest Significant Difference test for unequal subjects.24 Table 1

presents the group means (SDs) for athletes. The group with no

history of concussion reported fewer symptoms than both the single

concussion group (P=.04) and the multiple concussion group

(P\*.001) on the concussion symptom inventory. Baseline symptoms

increased as the number of concussions increased. On Trails B, the

multiple concussion group performed significantly worse at baseline

than the group with no history of concussion (P=.02) and the single

concussion group (P\*.001). Baseline data also differed significantly

on the SDMT with the multiple concussion group performing worse

than both the group with no history of concussion (P=.008) and the

single concussion group (P\*.001). These findings are not attributed to

preexisting group differences in terms of aptitude as the multiple

concussion group had higher SAT and ACT scores than did the group

with no history of concussion and the single concussion group. The

table presents demographic and neuropsychological test data for the

group with LD and the group without LD.

To investigate the interplay between concussion history and LD on

baseline neuropsychological test performance, a concussion history

and LD interaction term was constructed. Univariate F tests for all 10

neuropsychological variables demonstrated statistically significant

interactions for Trails B (F=4.99; P=.007) and SDMT (F=4.74;

P=.009). In both cases, athletes with a history of multiple

concussions and LD performed significantly worse than did athletes

with no history of LD who had experienced multiple concussions

(Figure 1).

In-Season Concussions

Nineteen players in the study sample were diagnosed by team

medical staff as sustaining a concussion during the course of the

1997-1999 seasons. Thirteen individuals sustained a grade 1

concussion (mental status abnormalities resolved within 15 minutes),

4 athletes sustained a grade 2 concussion (mental status

abnormalities that lasted longer than 15 minutes, but resolved within

45 minutes), and 2 athletes sustained a grade 3 concussion (brief

[approximately 5-10 seconds] loss of consciousness). The time

between baseline testing and in-season c

Bibliography

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