A Retrospective Clinical Analysis of Moderate to Severe Athletic Concussions

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Objective: To investigate differences in clinical outcomes on the basis of gender and age after a moderate or severe concussion in a cohort of physically active subjects examined by a single clinician.

Design: A descriptive, cross-sectional, retrospective chart review of consecutive patients.

Setting: Outpatient assessments by a single clinician with expertise in sports concussion.

Patients: Physically active subjects seen for evaluation after a concussion experienced while participating in sports (N = 194; 215 concussions; age mean ± standard deviation = 19.19 ± 8.53 years) were included.

Interventions (Independent Variables): Intergroup differences and associations were examined by gender, age group (<18 years and 18+ years), and concussion grade for all outcome measures.

Main Outcome Measurements: Separate χ^2 tests were used to assess associations between gender, age group, and symptom duration group (≤7 days, 8-90 days, >90 days), the presence of depression, the presence of loss of consciousness, altered school or work, and concussion grade. Separate independent samples *t*-tests was used to examine differences in symptom reporting and time to recovery.

Results: No association was observed between gender and any measured characteristics ($P > .05$). Subjects 18 years or older took longer to recover (315.77 days), compared with younger subjects (91.31 days) ($t_{213} = -2.01$, $P = .049$). Older subjects also reported more concussions than did younger ones, 4.33 and 2.37, respectively ($t_{213} = -3.77$, $P < .001$).

Conclusions: All concussions included in this study were moderate to severe in nature as defined by the Revised Cantu Grading Scale. Contrary to existing literature regarding gender differences in concussion of a lesser severity, no gender differences were observed in this sample. Age differences were observed, with the population of subjects who were 18 years and older experiencing a greater number and duration of concussion symptoms than the younger group. Developing evidence-based return-to-play progressions and rehabilitation strategies in this population is the next frontier for concussion researchers.

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INTRODUCTION

Cerebral concussion can be a disabling injury that affects both children and adults. Symptoms that appear after concussive injury are classified as somatic (eg, headache, nausea, vomiting, and balance problems), cognitive (eg, feeling slowed down, feeling in a fog, and having difficulty concentrating or remembering), and neurobehavioral (eg, fatigue, sadness, and nervousness). These symptoms, which can present in an acute, delayed, or chronic fashion, often negatively affect quality of life. In literature concerning the cumulative effects of concussion, investigators have described increased risk of depression [1], memory problems [2], and subsequent injury [3,4]. In younger athletes, multiple concussions may result in prolonged recovery and negatively affect performance at school [5,6]. In addition, these younger athletes may be at greater risk for injury [7]. School-age athletes may have difficulties in school as a result of concussion [5,6]. It is important to understand differences across age groups to better understand differences in management and recovery.

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Table 1. *Cantu Grading Scale (12)*

Grade 1 (mild)	No LOC/PTA <30 min, PCSS <24 h
Grade 2 (moderate)	LOC <1 min or PTA >30 min but <24 h or PCSS >24 h but <7 d
Grade 3 (severe)	LOC ≥1 min or PTA ≥24 h or PCSS >7 d

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LOC = loss of consciousness; PCSS = postconcussion signs/symptoms other than amnesia; PTA = posttraumatic amnesia (anterograde/retrograde).

Recently, attention has shifted to gender differences in both occurrence of concussion and deficits after a concussive injury. A 2008 study of United States high school and collegiate athletes observed a greater incidence of concussion in female soccer and basketball athletes compared with their male counterparts [8]. Other authors suggest that female athletes who have sustained a concussion are more likely to report a greater number and severity of symptoms [9] and may perform differently on measures of neuropsychological performance [9-11]. This combined body of literature illustrates the importance of properly understanding, recognizing, and managing concussion in persons across gender. Much of the aforementioned literature has focused on collegiate-age and high school–age athletes, with little attention devoted to age differences after injury. In this study we sought to investigate a unique sample of sport-concussed subjects, all of whom were diagnosed and managed by a single neurosurgeon and who sustained moderate to severe concussive injuries during the period of 2007 to 2008.

The purpose of this study was to describe characteristics of a unique sample of subjects after they experienced a moderate to severe concussive injury and to assess associations of gender, age, and concussion characteristics such as symptom duration, number and proximity of previous concussions, loss of consciousness (LOC), and amnesia.

METHODS

Two hundred fifteen office consultations by a single clinician (194 patients; age mean ± SD = 19.19 ± 8.53 years) during a 2-year period (2007-2008) for sport-induced concussion were studied with use of a structured chart review. No institutional review is required for this type of research at the study institution. Only concussions experienced during sports activity were included in the study. Two hundred forty-seven charts were screened and 53 were excluded on the basis of non–sport-related injury. All subjects were either active or retired athletes experiencing symptoms after a concussion. Data collected included age; gender; self-reported past medical diagnosis of depression and/or attention deficit disorder (ADD) or attention deficit hyperactivity disorder (ADHD); sport played; mechanism of injury; frequency of concussion; severity of concussion; and the number, type, and duration of symptoms. Symptom assessment was performed via a direct clinical interview. Each incident concussion evaluated in this study was graded for severity with use of the Cantu revised scale (Table 1) [12]. Also charted was whether cognitive adjustments were required for school or work.

Previous concussion data were collected, including the number of previous concussions, time between concussions, and concussion grade. Information regarding symptom presence, duration, and severity for previous concussions also was obtained. Results were computed with use of general descriptive statistics and χ^2 analyses where appropriate to assess general associations between gender, age group, and grade of concussion. Where expected counts were less than 5, Fisher exact tests were used, and only a P value is reported. Alpha level was set to 0.05 a priori for all analyses. Separate independent samples t-tests were used to examine differences in symptom reporting and time to recovery.

RESULTS

Total Sample Characteristics

Consecutive athletic concussions seen during a 2-year period were included in this descriptive study. This total included 215 concussions with 68 (31.6%) of these concussions sustained by female subjects and 147 (68.4%) of these concussions sustained by male subjects who ranged in age from 10 to 62 years. The majority of concussions (n = 145; 67.4%) were sustained by subjects younger than 18 years. A first concussion was the type most frequently observed (n = 78; 27.0%), followed by a second concussion (n = 77; 26.5%), and a third concussion (n = 47; 21.9%). Overall, 19 (8.8%) of the concussions were sustained by subjects with a diagnosed history of clinical depression, and 8 (3.7%) were sustained by subjects with a previous diagnosis of ADD/ADHD. Table 2 presents subject characteristics regarding age and clinical characteristics. Table 3 presents

Table 2. *Subject characteristics*

	Gender		Age Group	
Variable	**Male**	**Female**	**≤17 y**	**≥18 y**
Age (y)	19.07 ± 8.85	19.43 ± 7.84	15.12 ± 1.69	27.61 ± 10.62
No. of concussions	3.02 ± 2.82	2.97 ± 2.75	2.37 ± 1.27	4.33 ± 4.26
Duration of symptoms, d	194.18 ± 681.29	100.00 ± 130.15	91.31 ± 234.83	315.77 ± 924.67
No. of symptoms	11.45 ± 5.86	12.91 ± 6.28	12.12 ± 5.92	11.49 ± 6.14

Values in table are means ± SD.

Table 3. *Description of concussion characteristics and outcomes (N = 215 concussions)**

Variable	Reporting Yes in Sample n (%)	Gender		Age Group	
		Male (n = 147) n (%)	Female (n = 68) n (%)	<18 y (n = 145) n (%)	≥18 y (n = 70) n (%)
Return to play	89 (41.4)	61 (41.5)	28 (41.2)	63 (43.4)	26 (37.1)
Depression	63 (29.3)	41 (27.9)	22 (32.4)	40 (27.6)	23 (32.9)
Loss of consciousness	69 (32.1)	46 (31.3)	23 (33.8)	49 (33.8)	20 (28.6)
Altered school/work	69 (32.1)	50 (34.0)	19 (27.9)	50 (34.5)	19 (27.1)
Grade 3 concussion	186 (86.5)	126 (85.7)	60 (88.2)	124 (85.5)	62 (88.6)

*The columns in this table do not add up to 100% because each row is descriptive of the characteristic across the portion of the sample mentioned in the column heading.

descriptive data related to symptoms and outcomes for the incident concussions (those evaluated by the lead investigator).

According to the revised Cantu grading scale, 186 (86.5%) of the 215 concussions observed were grade 3, and 65 (30.2%) resulted in subjects reporting a symptom duration that qualified as postconcussion syndrome (symptoms >90 days). By using a classification scheme [13] in which we identified patients with prolonged recovery as lasting 1 month or longer, we found that 111 (51.6%) of the concussions resulted in subjects presenting with symptoms in this range. Of the total 215 concussions, approximately one third (n = 69; 32.1%) resulted in patients reporting an alteration in work or school as a result of the concussion.

In this cohort, American football (n = 53; 24.7%) represented the sport that was associated with the most concussions, followed by ice hockey (n = 51; 23.7%) and soccer (n = 32; 14.9%). The overall reported mechanisms of injury for the 215 concussions were contact between head and playing surface (n = 82; 38.1%,), followed by contact between head and other body part (n = 49; 22.8%) and head-to-head or helmet-to-helmet contact (n = 39;18.1%); however, the most common mechanism within sports differs. In football, head-to-head or helmet-to-helmet contact was the most common mechanism (n = 28/53; 52.8%); in hockey, contact between head and playing surface was the most common mechanism (n = 25/51; 49.0%); and in soccer, contact between head and equipment (n = 9/32; 28.1%) and contact between head and playing surface (n = 9/32; 28.1%) were the most common mechanisms.

Concussion Grade

No association was found between grade of concussion and grouped (1-2 or 3+) concussion history ($\chi^2 = 0.038$, $P = .845$), LOC (incident concussion; $\chi^2 = 0.524$, $P = .469$), or depression (incident concussion; $\chi^2 = 0.432$, $P = .511$).

Gender Differences

Although not statistically significant, 5 concussions sustained by female subjects resulted in a recovery of less than 7 days (7.4%) compared with 24 concussions (16.3%) sustained by male subjects during this same period (Table 4). Additional analyses revealed no association between gender and diagnosis of depression ($\chi^2 = 0.447$, $P = .504$). With respect to incident concussions, there was no association between gender and grade of concussion ($\chi^2 = 0.253$, $P = .615$) or the presence of LOC ($\chi^2 = 0.137$, $P = .712$). However, the overall prevalence of LOC was relatively high in the total sample of concussions, with 69 of 215 injuries (32.1%) resulting in LOC. Depression was reported as a symptom after 63 of 215 injuries (29.3%), with 7 of the these 63 depressive reports occurring in people self-reporting a previous diagnosis of clinical depression.

Age Differences

A significant association was found between age groups and symptom duration, with subjects older than 18 years being more likely to experience symptoms for longer than 90 days (Table 5). A significant difference in the mean duration of symptoms ($t_{213} = -2.01$, $P = .049$) and in the number of concussions ($t_{213} = -3.77$, $P < .001$) also was found in the older group (>18 years; Table 2). No association was found between age group and grade of concussion, LOC, or depression ($P > .05$).

Table 4. *Symptom duration groups frequencies by gender*

Gender	<7 Days n (%)	7-89 Days n (%)	>90 Days n (%)	χ^2 Value
Male	24 (16.3)	78 (53.1)	45 (30.6)	$\chi^2 = 3.65$
Female	5 (7.4)	43 (63.2)	20 (29.4)	$P = .161$

Table 5. *Symptom duration group by age*

Age(y)	<7 Days n (%)	7-89 Days n (%)	>90 Days n (%)	χ^2 Value
≤17	18 (12.4)	95 (65.5)	32 (22.1)	$\chi^2 = 18.99$
≥18	11 (15.7)	26 (37.1)	33 (47.1)	$P < .001$

DISCUSSION

The subjects described in this study represent characteristics of moderate to severe concussion, which have been reported less frequently than other types of concussion in the literature. The majority of these incident concussions resulted in symptoms lasting significantly longer than the 7 to 10 days most often reported for high school and collegiate athletes [14,15]. Although gender does not appear to be a factor in the duration of symptoms in this sample, the adults (≥18 years) experienced symptoms, on average, for approximately 50 days longer than did the youth/adolescent patients. These age differences in recovery raise issues surrounding lifetime cumulative effects of concussion and the strong likelihood that subconcussive injuries, combined with concussive injuries, present a dose-response with respect to overall symptomatology and recovery. This sample is different from those previously reported in the literature because a single clinician conducted all the evaluations. As mentioned, the majority of the concussions experienced in this clinical sample resulted in extended recovery periods beyond 7 to 10 days.

Overall Sample

The majority of the sample reported a much longer duration of symptoms and time to return to play compared with most previous literature examining sport concussions, in which the authors have suggested recovery between 7 and 10 days after injury [15-18]. In most of those studies, the athlete being asymptomatic was the indicator of recovery. However, a growing body of literature suggests that there may be many deficits after concussion, including postural control [19,20], cognitive issues [21], and underlying neurologic complications [22] that may not resolve in 7 to 10 days.

Advanced physiological technology, such as functional magnetic resonance imaging [23] and electroencephalography [24], indicate that there may be alterations in brain function extending beyond this typical 7- to 10-day window. More advanced postural control assessment, including Sensory Organization Testing and calculation of approximate entropy, also may suggest this extended recovery period [19,20]. These studies support the notion of many concussive injuries resulting in recovery periods extending beyond the typical 7- to 10-day window, and clinicians should be aware of the possibility of these extended recovery periods.

A large proportion of the concussions experienced by our subjects were their first concussions, and an association did not exist between the number of concussions and the severity of the evaluated injury. This finding is similar to that of a study of collegiate athletes [3,15]. A lack of association between previous concussion history and grade of current concussion emphasizes that each concussion should be treated on an individual basis. Our findings may compliment those of Giza and Hovda [25], who propose a cascade of events involving a chemical imbalance that last several days after a concussive injury. Along with the evidence suggesting a more delayed recovery, some investigators suggest that recovery can continue for weeks [26,27] and even years [28] after injury. The senior author (R.C.C.) has personal experience with 4 patients (R.C.C., unpublished data) who recovered from postconcussion syndrome after experiencing 2 years of symptoms and one patient who recovered after experiencing 5 years of symptoms.

This study also found a much greater presence of reported brief LOC (32%) and depression (29%) compared with the results from previous studies [15,29]. The greater incidence of brief LOC may be attributed to the careful history obtained from the athlete rather than relying solely on on-field observations. It bears mentioning that the great majority (88.4%) of athletes fit the Cantu Grade III [12] severity level based on duration of symptoms (≥7 days) rather than LOC longer than 1 minute. The unusually high incidence of depression may be attributed to the nearly 15% in the total sample who were diagnosed with depression before sustaining the concussion. Recent imaging studies have indicated changes in brain function related to areas that could contribute to depressive symptoms after injury [30,31].

Despite the increased presence of these 2 symptoms, neither was linked to grade of concussion, further indicating that brief LOC may not serve as a reasonable isolated marker of concussion severity. However, no mild concussions (resolving in <7 days) were part of this dataset; therefore, comparisons with this type of mild injury cannot be made. Another important characteristic of the data is that 34% of those sampled reported an alteration in school or work as a result of the concussion. This finding emphasizes that concussion often has a detrimental effect on quality of life, especially cognitive function. Previous literature has suggested effects on school performance in high school athletes [6] and effects on memory and mental well-being later in life [1,2].

Gender Differences

Although not statistically significant, we observed a trend of fewer concussions sustained by female subjects, 7.4% versus 16.3%, who recovered in the first 6 days after injury; however, too few subjects displayed this short symptom duration to know whether this trend would continue. Despite this finding, the average length of recovery was similar between male and female subjects, suggesting that symptom recovery is no different between male and female athletes who have sustained moderate to severe concussion.

Covassin et al [9] suggested that female subjects were more likely to report a greater number of concussive symptoms than were male subjects; however, our data do not support this finding. A recent study [32] is concordant with our findings, suggesting no clinical association between gender and the number or presence of symptoms after concus-

sive injury. No other significant findings related to associations with gender were found, suggesting overall minimal to no gender differences related to characteristics of concussion evaluated in this study. As a result of the uniqueness of this study's population compared with other studies, some of these results may differ from those of other studies in which the authors suggest gender differences [8-10].

Age Differences

The findings of our study suggest that subjects 18 years or older with more complicated concussions may be more likely to report symptoms lasting longer than 90 days, with a greater average duration of symptoms than that experienced by persons younger than 18 years. This finding may be explained by the significantly greater number of concussions experienced by the older group or perhaps by the effects of increased plasticity in the younger brain. No other age-related differences surrounding symptom presence, outcomes, or characteristics of concussion were found.

Study Limitations

It should be noted that these data were obtained from a single clinician's evaluation of these injuries, which presents some bias in the sample. However, these findings illustrate the need for further research concerning more moderate to severe cerebral concussions. We also recognize a potential limitation that this sample does not represent the preponderance of concussions classified as "mild."

CONCLUSION

Findings in the study sample—among whom nearly 90% experienced symptoms longer than 1 week and more than 50% qualify as postconcussion syndrome with symptoms lasting longer than 1 month—strongly indicate that a large number of concussions sustained by athletes may not resolve within the typical 7- to 10-day time span after injury. Applications of these findings are limited to moderately and severely concussed athletes. In addition, the study was retrospective in nature. The data may be skewed and less generalizable as a result of the clinical sample and self-report data used to obtain ADHD/ADD and depression history. However, these findings underscore the need for further athletic concussion research, especially on this population with prolonged symptoms that largely has been understudied. Individual management of each injury and an emphasis on delaying return to activity until patients have completely recovered from the previous concussion is paramount. Developing evidence-based return-to-play progressions and rehabilitation strategies in this population is the next frontier for concussion researchers.

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