

Original Article

Recovery from sports-related concussion: Days to return to neurocognitive baseline in adolescents versus young adults

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Abstract

Background: Sports-related concussions (SRC) among high school and collegiate athletes represent a significant public health concern. The Concussion in Sport Group (CIS) recommended greater caution regarding return to play with children and adolescents. We hypothesized that younger athletes would take longer to return to neurocognitive baseline than older athletes after a SRC.

Methods: Two hundred adolescent and young adult athletes who suffered a SRC were included in our clinical research cohort. Of the total participants, 100 were assigned to the 13-16 year age group and 100 to the 18-22 year age group and were matched on the number of prior concussions. Each participant completed baseline and postconcussion neurocognitive testing using the Immediate Post-Concussion assessment and Cognitive Testing (ImPACT) test battery. Return to baseline was defined operationally as post-concussion neurocognitive and symptom scores being equivalent to baseline using reliable change index (RCI) criteria. For each group, the average number of days to return to cognitive and symptom baseline were calculated. Independent sample *t*-tests were used to compare the mean number of days to return to baseline.

Results: Significant differences were found for days to return to baseline between 13-16 year olds and 18-22 year olds in three out of four neurocognitive measures and on the total symptom score. The average number of days to return to baseline was greater for 13-16 year olds than for 18-22 year olds on the following variables: Verbal memory (7.2 vs. 4.7, $P = 0.001$), visual memory (7.1 vs. 4.7, $P = 0.002$), reaction time (7.2 vs. 5.1 $P = 0.01$), and postconcussion symptom scale (8.1 vs. 6.1, $P = 0.026$). In both groups, greater than 90% of athletes returned to neurocognitive and symptom baseline within 1 month.

Conclusions: Our results in this clinical research study show that in SRC, athletes 13-16 years old take longer to return to their neurocognitive and symptom baselines than athletes 18-22 years old.

Key Words: Age, concussion, immediate post-concussion assessment and cognitive testing, mild traumatic brain injury, sports

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INTRODUCTION

In the United States, 1.7-3.8 million traumatic brain injuries (TBI) occur each year, and over 300,000 are due to sports and recreational activities.^[1,10] During the last decade, emergency department visits for sports-related TBIs among children and adolescents in the United States increased by 60%.^[10] Concussion, also termed mild traumatic brain injury (mTBI), is broadly defined as a trauma-induced physiologic disruption of brain function.^[2,18] Sports-related concussions (SRC) comprise nearly 9% of all injuries sustained during athletics.^[14] Football causes the highest number and percentage of concussions at the high school and collegiate levels, and soccer is most common cause of concussion in female athletes.^[12,22] SRC represent a growing problem that affects athletes at the junior and high school, collegiate, professional, and recreational levels.

Early studies conducted in the 1980s are believed to have overestimated concussion incidence, reporting rates in high school football to be as high as 15-20% compared to 10% at the collegiate level.^[13,29] Data from the National Athletic Trainers' Association from 1995 to 1997 reported high school SRC rates at 3.6% compared to 4.8% at the collegiate level.^[8,26] Most recently, Gessel *et al.* reported the incidence of SRC among high school athletes is 3-6%.^[14] Concussions make up nearly twice the proportion of total injuries at the high school level compared to the collegiate level.^[14] In the midst of conflicting data, we can conclude that varying rates of SRC at the high school and collegiate level among different age groups represent a growing problem necessitating national attention.^[6,30]

In 2008, the third meeting of the Concussion in Sport Group (CIS) was held in Zurich.^[25]

CIS delineated several "modifying" factors that influence investigation and management of concussions and prolonged symptoms, such as number of previous concussions, prolonged loss of consciousness, medication status, and other biopsychosocial factors. The consensus reached was that age <18 years is considered a modifying factor. The international group concluded: "Because of the different physiological response and longer recovery after concussion and specific risk related to head impact during childhood and adolescence, a more conservative return to play approach is recommended. It is appropriate to extend the amount of time of asymptomatic rest and/or the length of the graded exertion in children and adolescents."^[25]

To date, two papers have addressed empirically age-related concussion outcome. In 2003, Field *et al.*,^[11] in a controlled prospective study, published the initial reference paper on age-related concussion outcome by demonstrating that high school athletes took longer

to recover from SRC than college athletes. Field and colleagues compared paper and pencil neurocognitive test data from 19 high school and 35 collegiate athletes who sustained a SRC to control groups. Following injury, athletes were assessed within 24 hours of injury, and at days 3, 5, and 7 postinjury. Results showed that collegiate athletes had significant memory impairment only within the first 24 hours after injury, whereas high school athletes had memory impairment up to 7 days postconcussion. However, the collegiate group had sustained an average of 1.48 previous concussions versus 0.56 in the high school group. This difference bordered on statistical significance ($P = 0.07$).

More recently, Baillargeon *et al.*^[4] evaluated this consensus opinion empirically by studying 96 athletes after SRC, concluding that adolescents are more sensitive to the consequences of concussions than children or adults.^[4] The authors enlisted 96 male athletes and divided them into three age groups: 9-12 years, 13-16 years, and adults ($M = 23.3$ years, $SD = 3.3$ years). Each group was divided again into nonconcussed versus concussed. All athletes underwent a battery of paper and pencil neuropsychological tests in addition to electrophysiological testing. Results showed that there were essentially no significant differences among groups on all seven neuropsychological tests, with the single exception being a lowered memory test score in adolescents. All concussed participants showed decreases in electrophysiological testing, with no group differences. From this single significant difference (among the seven neuropsychological tests conducted), the authors concluded that adolescents were more vulnerable to concussion than adults.

Athletic trainers and team physicians are forced with the challenging situation of deciding when to return an athlete to play. Guidelines for return to play (RTP) have been extensively published,^[6,20,21,23] but it can be difficult to make specific, individualized RTP decisions based on population-based measures. Data on how age specifically impacts response to concussive injury and subsequent RTP would be of great clinical utility to team athletic trainers and physicians.

In this clinical research study we endeavored to assess acute neurocognitive and symptom recovery trajectories after SRC between two different age groups. We hypothesized that younger athletes would take longer to return to neurocognitive baseline than older athletes after a SRC.

MATERIALS AND METHODS

Study design

Institutional Review Board approval (IRB) was obtained prior to data collection. Our study was clinical, retrospective, and observational in nature. Participants

were recruited from high schools and colleges in the Western Pennsylvania area from 2009 to 2011 as part of a regional neurocognitive testing program. Following written, informed consent (by the athlete or his/her parent/guardian), all athletes underwent baseline neurocognitive testing as part of routine athletic care. Baseline testing was completed prior to each athlete's respective season. Baseline neurocognitive testing was conducted at each athlete's respective school, in a controlled environment (group setting) with minimal distractions. Postconcussion testing was conducted individually in controlled medical settings.

Selection of participants

Following head injuries, concussion was diagnosed based on the on-field presentation of one or more of the following signs or symptoms: (1) self-reported postconcussive symptoms, such as lethargy, fogginess, headache, etc., (2) alteration in mental status, (3) loss of consciousness, or (4) amnesia. The initial concussion diagnosis was made by a sports medicine athletic trainer or a team physician of one of the competing teams. Following the recommendations of the CIS consensus guidelines, no grading system was utilized for concussion severity.

The inclusion criteria for the current study was (1) age 13-16 years or 18-22 years at time of concussion, (2) participating in high school or collegiate athletics, (3) valid preparticipation baseline neurocognitive test data, (4) valid completion of up to two postconcussion neurocognitive testing data points within 30 days of the concussion (defined operationally as an ImpACT impulse control composite score of >30),^[3] and (5) fluency in English. Exclusionary criteria were (1) ages <13 , 17, or >22 years, (2) invalid baseline or postconcussion neurocognitive test scores, (3) self-reported history of special education, speech therapy, repeated year(s) of school, learning disability, ADHD, dyslexia, or autism, (4) self-reported history of brain surgery or seizure disorder, and (5) self-reported history of treatment for drug/alcohol abuse or psychiatric illness. We purposely omitted athletes 17 years old in order to clearly delineate the two cohorts on the age variable.

Matching of age cohorts

The final sample of the study participants was formulated by the following process. From the aforementioned database of athletes, 740 participants who previously completed baseline ImpACT testing and suffered a SRC were identified. Of these 740 athletes, 126 were outside of the age range of our study, and 112 had a history of special education, speech therapy, repeated year of school, or learning disability, and were excluded from the study. Of the remaining 502 eligible participants who sustained a concussion during the study period, 200 participants (100 in the 13-16 year range and 100 in the 18-22 year range) who had completed at least

two postconcussion ImpACT tests within 30 days of the concussion were matched based on the number of prior concussions, and subsequently included in the study. The flow-chart showing the patient inclusion into the study is included in Figure 1. For our study we selected athletes who had been tested at least twice within 30 days of the concussion in an attempt to (a) parallel typical clinical practice, and (b) compensate at least partially for the absence of a standardized research protocol. The 13-16 and 18-22 year old cohorts all met inclusion/exclusion criteria and were successfully matched based on the number of prior concussions.

Data collection and neurocognitive/symptom assessments

We chose to use the ImpACT test battery to obtain baseline neurocognitive test/symptom data. ImpACT is a commercially available computerized test for SRC that provides symptom and neurocognitive test data.^[24] ImpACT provides composite scores of verbal memory, visual memory, visual motor (processing) speed, reaction time, and impulse control. In addition to these neurocognitive scores, ImpACT includes a symptom inventory, the postconcussion symptom scale (PCSS). The PCSS is a concussion symptom inventory consisting of 22 7-point Likert scales for postconcussion symptoms.^[23] Previous studies have shown ImpACT to be reliable^[9,16,23,27] and valid^[15,17,28] in the assessment of SRC. In the current study, raw ImpACT scores were recorded for the composites of verbal memory, visual memory, visual motor (processing) speed, reaction time, impulse control, and total symptoms.

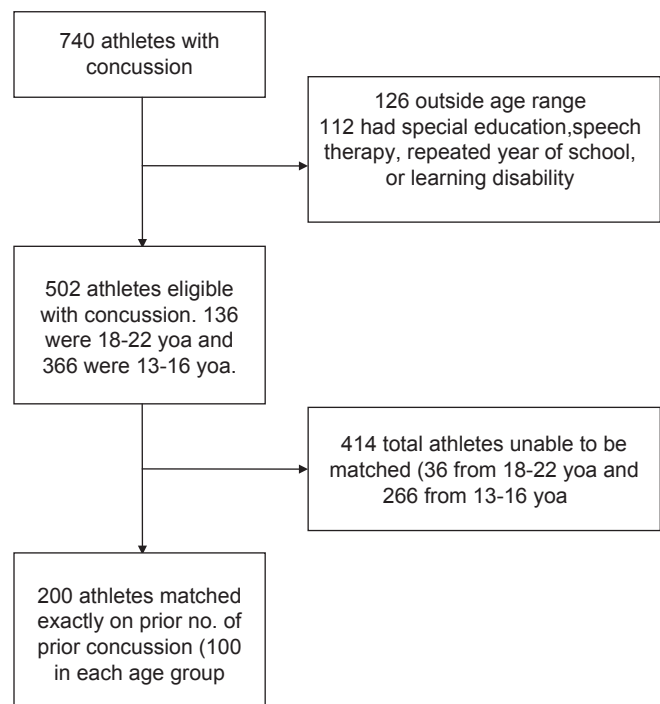


Figure 1: Flow-chart showing the patient inclusion into the study

Patients in this clinical research study were administered up to two postconcussion ImPACT tests. These tests were performed on separate days within 30 days of concussion. In this clinical research study, testing was dictated by clinical factors as opposed to a standardized research protocol. The primary dependent variable was operationally defined as the number of days until the postconcussion test scores returned to the participant's own baseline for all of the neurocognitive and symptom indexes. Utilizing a reliable change index (RCI) set at the 80% confidence interval,^[16] raw change scores equal to or greater than 8.75 points for verbal memory, 13.55 points for visual memory, 0.06 points for reaction time, 4.98 points for processing speed, and 9.18 points for PCSS met criteria for a statistically significant change. Any difference between post-concussion score and baseline less than these values was defined as a return to baseline.

Statistical analysis

Descriptive statistics are reported as mean and standard deviation for continuous variables and as frequency and proportion for categorical variables. Means and standard deviations of the ImPACT composite scores for both 13-16 year old and 18-22 year old groups were assessed at baseline and at both postconcussion test dates. For participants returning to baseline within the 30-day study

period, the number of days to return to baseline for each of the ImPACT neurocognitive and symptom scores was computed. For each composite score, the mean number of days to return to baseline was compared between the two age groups using an independent samples *t*-test. The significance of the difference between the 13-16 year olds and the 18-22 year olds for these measures was evaluated at $\alpha = 0.05$. None of the participants included in the final analyses had any missing data. Statistical analyses were performed by using IBM SPSS Statistics, Release Version 20.0.0 (IBM Corp., 2011, Chicago, IL, www.spss.com).

RESULTS

The 200 participants in our cohort allowed for exactly 100 participants in the 13- to 16-year-old age group and 100 participants in the 18- to 22-year-old age group. Table 1 provides the demographic characteristics of the athletes in both age groups. As expected, age and years of education were lower in the younger group. By virtue of the matching process, the number of prior concussions was equal (mean = 0.5, SD = .09) in both groups. Gender was not a controlled variable in this study. The gender distribution revealed a difference in age groups with 33 (33%) and 61 (61%) of the 13-16 year old and 18-22 year old groups being female, respectively.

Table 1: Demographic characteristics of participants (n = 200)

Characteristic	13-16 year (n = 100)		18-22 year (n = 100)	
Age, mean (SD)	15.1 (0.8)		19.1 (1.2)	
Female gender, (n, %)	33 (33)		61 (61)	
Right-handedness (n, %)	88 (88)		85 (85)	
Height, mean (SD)	171.7 cm (9.4 cm)		173.7 cm (11.0 cm)	
Weight, mean (SD)	68.5 kg (15.4 kg)		76.0 kg (19.8 kg)	
Body mass index, mean (SD)	23.0 (4.1)		24.8 (4.3)	
Number of years of education, mean (SD)	8.7 (1.0)		12.1 (1.5)	
Number of prior concussions, mean (SD)	0.5 (0.9)		0.5 (0.9)	
Type of sport, n (%)	Male (n = 67)	Female (n = 33)	Male (n = 39)	Female (n = 61)
Soccer	3 (4.5)	11 (33.3)	5 (12.8)	22 (36.1)
Football	51 (76.1)	0 (0.0)	23 (59.0)	0 (0.0)
Basketball	4 (6.0)	7 (21.2)	6 (15.4)	10 (16.4)
Wrestling	5 (7.5)	0 (0.0)	0 (0.0)	0 (0.0)
Cross-country	0 (0.0)	1 (3.0)	0 (0.0)	0 (0.0)
Tennis	0 (0.0)	0 (0.0)	0 (0.0)	2 (3.3)
Ice Hockey	1 (1.5)	0 (0.0)	1 (2.6)	2 (3.3)
Volleyball	0 (0.0)	1 (1.5)	0 (0.0)	2 (3.3)
Baseball	1 (1.5)	0 (0.0)	2 (5.1)	0 (0.0)
Softball	0 (0.0)	3 (9.1)	0 (0.0)	12 (19.7)
Cheerleading	0 (0.0)	7 (21.2)	0 (0.0)	4 (6.6)
Lacrosse	1 (1.5)	1 (3.0)	2 (5.1)	3 (4.9)
Track and field	0 (0.0)	1 (3.0)	0 (0.0)	0 (0.0)
Field hockey	0 (0.0)	1 (3.0)	0 (0.0)	3 (4.9)
Gymnastics	0 (0.0)	0 (0.0)	0 (0.0)	1 (1.6)
Unknown	1 (1.5)	0 (0.0)	0 (0.0)	0 (0.0)

The type of sport played also was not a controlled variable in this study. Among the 13- to 16-year-old males, approximately 76% were football players. The females in this younger age group comprised primarily soccer (33%), basketball (21%), and cheerleading (21%) athletes. In the 18-22 year group, football accounted for 59% of the male athletes while 16% played basketball and 13% played soccer. Females in the 18- to 22-year-old group came from the sports of soccer (36%), softball (20%), basketball (16%), and cheerleading (6%).

Table 1 also provides demographic data related to participants' lateral dominance, height, weight, and body mass index.

Baseline neurocognitive and symptom scores

Table 2 provides the mean scores of the two groups at baseline. T-tests were performed to assess for group differences. Significant between group differences were found on visual motor (Processing) speed and reaction time, with the 13- to 16-year-old group performing better on the former and the 18- to 22-year-old group performing better on the latter. The verbal memory score bordered on but did not reach statistical significance, with the 18- to 22-year-old group having a higher mean score. There were no significant group differences on visual memory or the PCSS scores.

Table 3 lists the percentages of athletes who returned to baseline neurocognitive and symptom scores (as measured by reliable change methodology) within 30 days. In both groups, greater than 90% of the participants returned to baseline within 1 month, and the recovery percentages were similar in both groups. The PCSS scores showed the highest percentage rate of return to baseline across both groups.

Days to return to baseline scores

The results for the average number of days taken by 13--16 year olds and 18-22 year olds to return to baseline scores are summarized in Table 4.

Paired *t*-tests ($\alpha=0.5$) were used to evaluate the significance of the differences between the 13-16 year-old and 18-22 year-old cohorts. The average number of days to return to baseline was greater for 13-16 year olds than for 18-22 year olds on verbal memory (7.2 vs. 4.7, $P =0.001$), visual memory (7.1 vs. 4.7, $P = 0.002$), reaction time (7.2 vs. 5.1 $P = 0.01$), and postconcussion symptom scale (8.1 vs. 6.1, $P = 0.026$). The difference between groups on visual motor (processing) speed (6.8 vs. 5.3, $P = 0.063$) bordered on, but did not reach, the conventional level of statistical significance.

DISCUSSION

We endeavored to assess acute neurocognitive and symptom recovery differences after SRC between two different age groups, hypothesizing that younger athletes would take longer to return to neurocognitive baseline than older athletes. Our results show that in this cohort, athletes 13-16 years old took several days longer to return to their neurocognitive and symptom baselines than athletes 18-22 years old. These results support the prior findings that younger athletes may take longer to recover to neurocognitive and symptom baseline than older athletes. We found baseline differences between the age groups on three of the neurocognitive indexes. This is not a surprising finding, since baseline normative values on ImPACT vary as a function of age, and normative values are age based. Further, the disparity between groups at baseline, in the vast majority of cases, has no direct effect on the amount of time it may take to return to an individual's baseline scores.

Our findings, despite being a retrospective clinical research study, offer some methodological advantages compared to the preexisting studies. Both prior studies^[4,11] contained relatively small sample sizes. The Field study drew conclusions from only 19 concussed high school and 35 concussed collegiate athletes. The Baillargeon study

Table 2: Baseline scores for the five-neurocognitive domains measured by the ImPACT program

Age (years)	Composite Scores				
	Verbal memory	Visual memory	Visual motor speed	Reaction time	Post-Concussion scale
13-16	83.0 (9.2)	72.0 (11.8)	40.0 (6.0)	0.58 (0.07)	6.0 (8.6)
18-22	85.0 (9.4)	71.4 (12.6)	37.0 (6.0)	0.56 (0.06)	7.3 (11.5)
P-value	0.083	0.611	0.002	0.015	0.363

Table 3: Number/percentage of participants that returned to baseline within a month as measured by a reliable change index value of 80% applied to ImPACT composite scores (n = 100 per age group)

Age (years)	Composite Scores				
	Verbal memory	Visual memory	Visual motor speed	Processing speed	Postconcussion scale
13-16	91	96	93	96	98
18-22	92	98	93	94	97

Table 4: Average number of days to return to baseline neurocognitive values by the age group

Composite scores	Age group (years)		P
	13-16 (mean, SD)	18-22 (mean, SD)	
Verbal memory	7.2 (5.6)	4.7 (4.6)	0.001*
Visual memory	7.1 (5.6)	4.7 (4.9)	0.002*
Reaction time	7.2 (5.8)	5.1 (5.2)	0.010*
Processing speed	6.8 (5.8)	5.3 (5.4)	0.063
Postconcussion scale	8.1 (6.8)	6.1 (5.4)	0.026*

divided 96 participants into six groups, leaving the largest subgroup at 17 athletes. The current study compared two groups of 100 athletes each, which minimally doubles the sample size of either of the previous studies. Furthermore, the current study controlled more precisely for previous concussion, which has been shown to significantly affect outcomes.^[5,7,19] Field *et al.* compared cohorts with varying number of prior concussions, with the difference in concussion history bordering on statistical significance.^[11] Baillargeon *et al.* did control for previous concussion.^[4] An additional methodological strength of the current study was the use of reliable change index (RCI) values in determining return to baseline neurocognitive and symptom scores. RCI is considered a relatively stringent and objective determinant in assessing return to baseline (or any performance change of significance). The RCI, in effect, allowed each athlete in this study to serve as his/her own control, given that RCI values were applied to individual baselines. Finally, we chose to demarcate the age factor more precisely by omitting athletes aged 17 years at the time of concussion. Our younger cohort ended at 16 years old, and our older cohort began at 18 years old.

Our study suffers several limitations. This was not a prospective, control group study driven by a research protocol, and postconcussion testing was not conducted at regularly scheduled intervals. Whereas the two prior studies utilized a standardized follow-up schedule for neurocognitive testing, our study collected clinical, retrospective data, where athletes' time of testing was mandated clinically. Our study describes the real-world follow-up of concussion, but without a standardized protocol and appropriate controls, our data must be viewed in the clinical context in which it was collected. The difference between the days to the first postconcussion test for the younger group ($M = 5.0$ days, $SD = 4.6$ days) and the older group ($M = 3.3$ days, $SD = 3.4$) was found to be statistically significant ($P = 0.003$). Second, our data analysis was completed retrospectively, in a cross-sectional manner. Third, groups were not matched on the variables of gender or sport. Finally, we did not assess athletes formally for effort using traditional clinical neuropsychological tests. Instead, we used the rule proposed by Lovell as a proxy for a formal

effort test.

Finally, we must emphasize that the current results do not reflect or indicate that athletes were cleared for a return to play postconcussion. This was not intended to be a "return to play" study. Neurocognitive test results and symptom scores are one piece of a larger return to play clinical decision-making process. Multiple factors must be taken into consideration when evaluating a player's safety to return to the field.^[25] Neurocognitive test results are not and should not be the sole parameter utilized when returning a player to sport. We do not view the mean days to recovery noted in the two age groups reported in this study to be interpreted as normative recovery values. In addition, we urge future researchers to attempt to utilize age-specific populations in concussion studies, as there appears to be age-specific responses to concussive injury in symptoms and neurocognitive scores. We interpret the results of this study to indicate that there are age-based differences in acute response (symptoms and neurocognitive scores) to concussive injury in young athletes. We view the results of our study as offering empirical support for the current CIS position regarding the role of age as a modifying factor in SRC, and also bolsters the CIS recommendation that younger athletes be managed more conservatively in return to play decisions.

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