Removal From Play After Concussion and Recovery Time

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abstract

OBJECTIVE: Despite increases in education and awareness, many athletes continue to play with signs and symptoms of a sport-related concussion (SRC). The impact that continuing to play has on recovery is unknown. This study compared recovery time and related outcomes between athletes who were immediately removed from play and athletes who continued to play with an SRC.

METHODS: A prospective, repeated measures design was used to compare neurocognitive performance, symptoms, and recovery time between 35 athletes (mean ± SD age, 15.61 ± 1.65 years) immediately removed after an SRC (REMOVED group) compared with 34 athletes (mean ± SD age, 15.35 ± 1.73 years) who continued to play (PLAYED group) with SRC. Neurocognitive and symptom data were obtained at baseline and at 1 to 7 days and 8 to 30 days after an SRC.

RESULTS: The PLAYED group took longer to recover than the REMOVED group (44.4 ± 36.0 vs 22.0 ± 18.7 days; $P = .003$) and were 8.80 times more likely to demonstrate protracted recovery (≥21 days) ($P < .001$). Removal from play status was associated with the greatest risk of protracted recovery (adjusted odds ratio, 14.27; $P = .001$) compared with other predictors (eg, sex). The PLAYED group exhibited significantly worse neurocognitive and greater symptoms than the REMOVED group.

CONCLUSIONS: SRC recovery time may be reduced if athletes are removed from participation. Immediate removal from play is the first step in mitigating prolonged SRC recovery, and these data support current consensus statements and management guidelines.

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DOI: 10.1542/peds.2016-0910

Accepted for publication Jun 6, 2016

WHAT'S KNOWN ON THIS SUBJECT: Immediate removal from play is recommended for athletes with suspected concussion. The majority of concussions go unreported, and the catastrophic consequences of continuing to play with concussion are documented. The impact of removal from play on recovery outcomes is unknown.

WHAT THIS STUDY ADDS: Athletes who were not removed from play took longer to recover and demonstrated worse neurocognitive and symptom outcomes after a sport-related concussion. Removal from play status is a new predictor for protracted recovery and supports consensus guidelines.

To cite: Elbin R, Sufrinko A, Schatz P, et al. Removal From Play After Concussion and Recovery Time. *Pediatrics*. 2016;138(3):e20160910

Approximately 1.6 to 3.8 million sport/recreation-related concussions (SRCs) occur annually in the United States.[1] In 2007, there were 250 000 emergency departments visits for SRC, more than double the rate in 1997.[2] Concussions result in symptoms (eg, headache, dizziness, nausea), impairment (eg, cognitive, vestibular, visual), academic and/or psychosocial problems, and recovery times ranging from days to months.[3] Adolescents are at greatest risk for SRC and experience longer recovery than adult athletes due to maturation or other unknown etiology.[4] Clinical guidelines recommend immediate removal from play if an athlete has a suspected SRC.[3,5,6] These guidelines are based on delayed onset of symptoms,[7,8] neurocognitive impairment,[9] and research indicating compromised neurometabolic function during the first 10 days' postinjury that increases the risk of a subsequent SRC.[10–14] These guidelines are also intended to reduce the risk of second impact syndrome, a rare but catastrophic condition that involves the loss of cerebrovascular autoregulation and brain herniation, and is often fatal among adolescent athletes who sustain brain injuries in short succession.[15,16]

The Centers for Disease Control's Heads Up concussion education program states, "It is better to miss one game than the whole season."[17] However, due to many factors, including the culture of sports (ie, play through injury),[18,19] poor awareness of SRC signs/symptoms,[20,21] and limited access to medical professionals, an estimated 50% to 70% of concussions go unreported/undetected.[20,22,23] In fact, in 2013, the Institute of Medicine and National Research Council stated that the culture of sports negatively influences SRC reporting and that athletes, coaches, and parents do not fully acknowledge the risks of playing while injured.[21] Researchers suggest that exposure to physical activity immediately after concussion decreases neuroplasticity and cognitive performance and increases neuroinflammation.[24,25] The physical exertion required for an athlete to remain in play after SRC may increase energy demand at a time when the brain is metabolically compromised[10,26] and lead to similar outcomes reported in animal models. Axonal injury, astrocytic reactivity, and memory impairment are also exacerbated following a second injury 24 hours after an initial injury.[10,27] The potential effects of continuing to play with an SRC have yet to be examined in adolescent and young adult athletes at risk for these adverse outcomes. The present study compared recovery time and related outcomes between athletes with an SRC who were immediately removed from play and athletes who continued to play with an SRC.

METHODS

Study Design and Participants

A prospective, repeated measures design was used for this study. Ninety-five athletes (aged 12–19 years) seeking care for an SRC at a concussion specialty clinic between September 1, 2014, and December 1, 2014, were recruited for the study. Inclusion criteria included: (1) enrollment in a patient research registry; (2) SRC diagnosis within 7 days of first clinical visit; (3) ability to recall the moment during a game or practice that they sustained a head impact resulting in on-field SRC symptoms (eg, dizziness) and/or changes in mental status (eg, posttraumatic amnesia); (4) no record of brain injury within the previous 3 months; (5) no diagnosed learning disability or hyperactivity disorder; (6) completion of a second clinical visit 8 to 30 days' postinjury; and (7) a retrievable, valid preinjury (ie, baseline) assessment of neurocognitive performance and symptoms from the referring medical professional in the clinic's health care network.

Outcome Measures

Definition of Sport-related Concussion

Concussions were diagnosed at the time of injury by a certified athletic trainer or sports medicine team physician on the basis of the following criteria: (1) clear mechanism of injury; and (2) the presence of ≥1 on-field sign of concussion (eg, loss of consciousness, amnesia, disorientation/confusion, balance difficulties), and/or ≥1 symptom (eg, headache, dizziness, nausea) after injury and any impairment according to sideline assessments (eg, Sport Concussion Assessment Tool).

Determination of Removal From Play Group Status

Demographic characteristics, medical history, and injury-related information were obtained via clinical interview from athletes, parents, and/or informants (eg, referring medical professional). A clinical intake form was used to determine study eligibility and assignment to removal from play groups (Table 1).

Neurocognitive and Symptom Impairment

The Immediate Post-Concussion Assessment and Cognitive Testing (ImPACT) was used to measure neurocognitive impairment. ImPACT is a computer-based neurocognitive battery that yields composite scores for verbal and visual memory, processing speed, and reaction time. ImPACT also includes the Post-Concussion Symptom Scale, which is a self-reported symptom inventory including 22 items that yields a total symptom severity score. Psychometric data on ImPACT and the Post-Concussion Symptom Scale have been published previously.[28–34]

TABLE 1 Questions on the Removal From Play Clinical Intake Form

Question	Response		Action
1. Can you recall the moment/event when you realized you might have sustained a concussion (ie, got your bell rung or dinged)?	Yes	No	If No = Athlete excluded from study
2. Did you experience any brief change in your mental status (eg, LOC, disorientation, memory difficulty)?	Yes	No	
3. Did you experience any concussion symptoms (eg, headache, dizziness, nausea)?	Yes	No	
4. Did you tell someone you were having symptoms?	Yes	No	
5. Were you removed from play?	Yes	No	If Yes = Removed If No = Played
6. How much longer did you play in the game/practice that you were injured in? (Number of minutes)			

Athletes who responded Yes to questions 1, 2 or 3, 4, and 5 were included in the study. LOC, loss of consciousness.

Recovery From SRC

Recovery time was defined as the total number of days from the date of injury to the date of receiving medical clearance from the clinician for full return to sports participation. Per international consensus,[3] athletes were required to be symptom-free at rest and after physical exertion before receiving medical clearance. Athletes were also required to demonstrate neurocognitive performance within normal limits (ie, 80% confidence intervals using reliable change indices) of their own baseline scores after exertion. When symptom-free at rest, athletes were asked to schedule a clearance appointment, which included neurocognitive testing and a standardized exertion test. Certified athletic trainers or physical therapists at the clinic administered exertion tests. Clinic policy allows for all athletes seeking clearance to be seen within 72 hours of appointment request, assuring that lack of appointment availability does not limit opportunity for return-to-play evaluation.

Procedure

All athletes were enrolled in a university institutional review board–approved concussion research registry. During each of 2 consecutive clinical visits, athletes completed ImPACT and the Post-Concussion Symptom Scale, followed by an in-person clinical interview conducted by a neuropsychologist trained in concussion. Neurocognitive and symptom data were gathered from athletes at 1 to 7 days and 8 to 30 days after injury. Follow-up visits are scheduled every 7 to 10 days, and clinic closures (eg, weekends and holidays) and patient availability can alter this schedule. To accommodate these factors, patients who completed visits within 2 to 3 weeks were enrolled. Baseline neurocognitive and symptom data from the referring institution were retrieved from medical records for each patient when available. All clinicians providing clinical care were blinded to patient group. On-field signs and symptoms of SRC were taken retrospectively via the clinical interview during the first clinical visit. Parents accompanied athletes to the clinic for all clinical visits and corroborated information in the event that the athlete could not recall his or her on-field signs and/or symptoms.

Data Analysis

Descriptive statistics (means, SDs, and frequencies) were used to describe the total sample and compare the REMOVED and PLAYED groups in terms of demographic characteristics and injury-related factors (Table 1). To ensure group equivalence for the elapsed time between the 2 postinjury clinical visits, a difference score was calculated between the second and first visits. A subsequent independent sample t test was conducted on the difference score to ensure group equivalence, and statistical significance was set at $P \leq .05$.

A series of 2 (group: REMOVED, PLAYED) × 3 (time: baseline, 1–7, 8–30 days), mixed-factorial analyses of variance were conducted to examine neurocognitive (verbal memory, visual memory, processing speed, and reaction time) and symptom (total symptom score) scores. After Bonferroni correction for these 5 analyses, statistical significance was set at $P \leq .01$.

An independent sample t test was used to compare recovery time (number of days) between the REMOVED and PLAYED groups. To examine protracted recovery, the number of days to recovery was dichotomously categorized as protracted (≥21 days) or normal (<21 days).[35] The χ^2 analyses with odds ratios (ORs) were performed to compare the risk of protracted recovery for the REMOVED and PLAYED groups. A logistic regression was conducted to identify the relative contribution of removal from play status among SRC modifying factors outlined in the literature (including age,[36] sex,[37] and posttraumatic migraine[35]) that predict protracted recovery. Effect sizes for interval/ratio data were denoted by Cohen's d and Cramer's V for nominal data. These analyses were conducted by using SPSS version 21.0 (IBM SPSS Statistics, IBM Corporation, Armonk, NY),[38] and statistical significance was set at $P \leq .05$.

RESULTS

Twenty-one percent (20 of 95) of the recruited sample did not have retrievable neurocognitive baseline and symptom data and were excluded. Three athletes with attention-deficit/hyperactivity disorder and 1 athlete with learning disability were excluded. Two athletes had a clinical visit interval time that was an outlier (>2.5 SD) and were excluded (eg, clinical visit 1 occurred at 6 days and the second clinical visit occurred at 8 days). The final sample consisted of 69 athletes, comprising 35 in the REMOVED group and 34 in the PLAYED group. One athlete in the REMOVED group had 4 previous concussions, and 2 athletes in the PLAYED group had 1 previous concussion. Due to the low reported number of concussions in this sample, concussion history was not entered into the logistic regression analysis.

There were no differences between the REMOVED and PLAYED groups on concussion history ($P = .65$). There were no differences between the PLAYED (10.1 ± 3.2 days) and REMOVED (8.9 ± 3.1 days) groups on the time elapsed from first clinical visit to the second clinical visit ($t[67] = 1.50$; $P = .14$), and the mean number of days between the first and second clinical visit was 9.5 ± 3.2 days (range, 4–16 days). Athletes participated in a variety of sports, including football (39% [27 of 69]), soccer (23% [16 of 69]), ice hockey (18% [13 of 69]), volleyball (7% [5 of 69]), field hockey (4% [3 of 69]), rugby (3% [2 of 69]), basketball (3% [2 of 69]), and wrestling (1% [1 of 69]). The representation of collision sports (eg, football, ice hockey, soccer, wrestling, rugby) did not differ between the REMOVED (45% [31 of 69]) and PLAYED (41% [28 of 69]) groups ($P = .46$). Athletes in the REMOVED group did not participate in any practice and/or game from the time of injury to their first clinical evaluation and enrollment in the study; athletes in the PLAYED group continued to play in competition or practice after injury for an average of 19.2 ± 13.0 minutes. There were no significant differences between the REMOVED and PLAYED groups in terms of demographic or current injury-related variables (Table 2).

TABLE 2 Comparisons of Demographic and Concussion-Related Variables Between the REMOVED (*n* = 35) and PLAYED (*n* = 34) Groups

Variable	REMOVED	PLAYED	*P*
Demographic variables			
Age, y	15.61 ± 1.65	15.35 ± 1.73	.55
Sex (% female)	23% (8/35)	29% (10/34)	.53
No. of previous concussions	0.11 ± 0.68	0.06 ± 0.24	.65
Migraine diagnosis	4	2	.41
Headache diagnosis	8	4	.22
Anxiety	2	0	.16
Family history of migraine	15	11	.32
Days until first clinical visit	3.31 ± 1.66	3.76 ± 1.81	.29
Days until second clinical visit	12.26 ± 3.66	13.85 ± 3.53	.07
On-field markers of SRC severity			
Amnesia	2	6	.12
Disorientation	2	1	.57
Loss of consciousness	1	1	.98
Confusion	1	1	.98
Vision changes	7	5	.56
On-field symptoms			
Headache	18	17	.91
Dizziness	10	11	.73
Vomit	1	0	.32
Balance	3	1	.32
Mental fogginess	4	2	.41
Nausea	4	3	.72
Fatigue	0	0	—
Numbness/tingling in extremities	1	1	.98
Sensitivity to light	0	0	—
Sensitivity to noise	0	2	.15

Comparison of Neurocognitive Performance and Concussion Symptoms Between the REMOVED and PLAYED Groups

A series of 2 (group) × 3 (time), mixed-factorial analyses of variance revealed significant group × time interactions for verbal ($\eta2 = 0.18$; $P = .002$) and visual ($\eta2 = 0.23$; $P \leq .001$) memory, processing speed ($\eta2 = 0.23$; $P \leq .001$), reaction time ($\eta2 = 0.20$; $P = .001$), and total symptom score ($\eta2 = 0.17$; $P = .002$) that were all significant. Baseline verbal ($P = .43$) and visual ($P = .31$) memory, reaction time ($P = .85$), and total symptoms ($P = .65$) were similar between groups. The REMOVED group had significantly higher processing speed at baseline compared with the PLAYED group ($P = .05$). As a result, baseline processing speed was used as a covariate for a series of post hoc between-group analyses of covariance. The post hoc analyses of covariance revealed that the PLAYED group demonstrated significantly worse verbal ($P = .001$) and visual ($P = .001$) memory, processing speed ($P \leq .001$), and reaction time ($P = .001$) and higher symptoms ($P = .001$) than the REMOVED group at 1 to 7 days. At 8 to 30 days' postinjury, the PLAYED group demonstrated worse verbal ($P = .009$) and visual ($P \leq .001$) memory and processing speed ($P = .001$), and greater symptoms ($P = .001$), compared with the REMOVED group. Reaction time did not differ between groups at 8 to 30 days' postinjury ($P = .09$).

Significant within-subject effects for time were also revealed for verbal ($\eta2 = 0.16$; $P = .003$) and visual ($\eta2 = 0.24$; $P \leq .001$) memory, processing speed ($\eta2 = 0.34$; $P \leq .001$), reaction time ($\eta2 = 0.24$; $P \leq .001$), and total symptoms ($\eta2 = 0.57$;

TABLE 3 Comparing Baseline and Postconcussion Neurocognitive and Symptom Scores Between the REMOVED (n = 35) and PLAYED (n = 34) Groups

Variable	REMOVED	PLAYED
Verbal memory		
Baseline	85.11 ± 9.39	83.44 ± 8.20
Days 1–7	86.11 ± 10.47**	71.29 ± 19.81
Days 8–30	88.60 ± 8.02*	77.65 ± 18.24
Visual memory		
Baseline	77.91 ± 11.57	75.00 ± 11.88
Days 1–7	76.09 ± 12.68**	63.35 ± 14.02
Days 8–30	79.11 ± 11.72**	63.47 ± 16.99
Processing speed		
Baseline	36.11 ± 6.68*	33.12 ± 5.76
Days 1–7	38.88 ± 6.99**	28.77 ± 8.06
Days 8–30	41.46 ± 6.65**	33.80 ± 9.16
Reaction time		
Baseline	0.60 ± 0.08	0.61 ± 0.07
Days 1–7	0.60 ± 0.10**	0.74 ± 0.18
Days 8–30	0.58 ± 0.10	0.68 ± 0.21
Total symptoms		
Baseline	2.17 ± 4.29	2.68 ± 4.85
Days 1–7	15.06 ± 15.27**	33.00 ± 24.14
Days 8–30	3.89 ± 8.01**	16.15 ± 16.07

P values significantly different from PLAYED score.
** $P \leq .001$.
* $P \leq .01$.

TABLE 4 Results of a Logistic Regression Examining Predictors for Protracted Recovery After SRC (N = 60)

Variable	Adjusted OR	95% CI for OR
Age	0.72	0.48–1.11
Sex	9.12	1.55–53.57
Posttraumatic migraine	4.13	0.80–21.44
Removal from play status	14.27	3.03–67.13

CI, confidence interval.

P = .001). Verbal memory (P = .006), visual memory ($P \leq .001$), reaction time (P = .001), and total symptom scores ($P \leq .001$) were worse at 1 to 7 days' postinjury compared with baseline; at 8 to 30 days' postinjury, visual memory (P = .005) and total symptoms ($P \leq .001$) remained significantly lower than baseline, whereas verbal memory (P = .99) and reaction time impairments resolved (P = .63). Processing speed was not lower than baseline at 1 to 7 days (P = .98) but higher than baseline at 8 to 30 days' postinjury (P = .001).

Between-subject group effects for verbal memory ($\eta 2$ = 0.16; P = .001), visual memory ($\eta 2$ = 0.19; $P \leq .001$), processing speed ($\eta 2$ = 0.24; $P \leq .001$), reaction time ($\eta 2$ = 0.12; P = .003), and total symptom score ($\eta 2$ = 0.20; $P \leq .001$) were all significant. The REMOVED group exhibited significantly higher verbal (P = .001) and visual ($P \leq .001$) memory, and faster processing speed ($P \leq .001$) and reaction time (P = .003), than the PLAYED group. The REMOVED group reported significantly fewer symptoms than the PLAYED group ($P \leq .001$) (Table 3).

Comparing Recovery Time Between PLAYED and REMOVED Groups

We were able to determine recovery time data for 62 (90%) of 69 athletes (30 in the PLAYED group and 32 in the REMOVED group). Seven (10%) of 69 athletes were lost to follow-up (ie, did not return to the clinic for a clearance visit during the study period). Independent sample t tests revealed that athletes in the PLAYED group experienced a significantly longer recovery time than those in the REMOVED group (d = 0.80; P = .003). The mean number of days from date of injury to medical clearance was 44.4 ± 36.0 days (range, 10–164 days) for the PLAYED group compared with 22.0 ± 18.7 days (range, 8–88 days) for the REMOVED group.

Twenty-four (80%) of 30 athletes in the PLAYED group and 10 (31%) of 32 athletes in the REMOVED group demonstrated a protracted recovery (≥21 days). Athletes in the PLAYED group were 8.80 times more likely to experience a protracted recovery compared with athletes in the REMOVED group (V = 0.49; P < .001). The logistic regression was significant (χ^2 [5, 60] = 27.07; P < .001) (Table 4). Removal from play status showed the greatest likelihood of protracted recovery (adjusted OR, 14.27; P = .001) followed by sex (adjusted OR, 9.12; P = .01).

DISCUSSION

To the best of our knowledge this study is the first to compare recovery outcomes of athletes with an SRC who were immediately removed versus athletes who continued to play with an SRC. Athletes who continued to play with an SRC required nearly twice as long to recover than those who were immediately removed from play (44 vs 22 days). These athletes demonstrated worse postinjury neurocognitive and symptom presentation at 1 to 7 days and at 8 to 30 days than athletes immediately removed from play. Removal from play status was also associated with a greater risk of protracted SRC recovery than other empirically supported factors. These results underscore the risks associated with continuing to play with an SRC, and they emphasize to athletes, parents, coaches, and on-field clinicians the importance of timely recognition and/or identification of the signs and symptoms of SRCs and immediate removal from play.

Prolonged recovery outcomes exhibited by athletes who continued to play with an SRC may be a consequence of continued physical exertion that exacerbates the pathophysiologic and metabolic events that underlie concussive brain injury.[10,27] Findings of the present study support experimental brain injury studies using animal models showing the deleterious effects (eg, decreased plasticity, increased neuroinflammation, worse cognitive performance) of continued exposure to physical activity after concussion.[24,25] The present study extends these findings to human subjects.

Although the majority of SRCs resolve within 3 weeks, ~20% of athletes with an SRC will experience a protracted recovery longer than this time frame.[39,40] In an effort to identify these athletes and provide acute management and treatment interventions, several factors that predict protracted recovery have been identified in the literature, including age,[4,36] concussion history,[8] sex,[37] and posttraumatic migraine.[35] The present study supports removal from play status as a new injury-related modifying factor for predicting protracted recovery.

There are limitations to our study. The sample was small and included a large number of male football players and female soccer players ranging in age from 12 to 19 years. As such, the results may not be generalizable to other groups of athletes. It is unclear what happened (eg, additional hits, noncontact running only) to athletes who continued to play. Accordingly, it is uncertain if the detrimental effects of continuing to play are related to additional impacts or continued physical exertion. Athletes were recruited from a specialty clinic, which limits the generalizability to concussed athletes who do not receive specialty referral and may represent a sample bias given the high incidence of personal and family history of migraine. On-field signs and symptoms were retrospectively obtained via patient and parent recall, which may be influenced by recall bias. Future studies should quantify additional head impacts and physical exertion in athletes who continue to play with an SRC to examine a dose–response relationship and include a larger, diverse sport sample. Future studies should examine predictors (eg, concussion history, sex, sport type) of voluntary removal from play behaviors after SRC.

CONCLUSIONS

Despite increases in awareness, athletes continue to play with SRCs[41] with fear of being removed from participation.[20] This study is the first to show that athletes who continue to play with an SRC experience a longer recovery and more time away from the sport. If athletes with a suspected SRC remove themselves or are removed by a medical professional, recovery time may be reduced. These data support the mantra of the Centers of Disease Control: "It's better to miss one game than the whole season."[17] These findings should be incorporated into SRC education and awareness programs for athletes, coaches, parents, and medical professionals.

ACKNOWLEDGMENTS

We thank Catherine Hilton for her assistance with data collection and entry for this study.

ABBREVIATIONS

ImPACT: Immediate Post-Concussion Assessment and Cognitive Testing
OR: odds ratio
SRC: sport-related concussion

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PEDIATRICS (ISSN Numbers: Print, 0031-4005; Online, 1098-4275).

FINANCIAL DISCLOSURE: Dr. Collins is a shareholder of ImPACT Applications, Inc; Dr. Schatz is a consultant for ImPACT Applications, Inc; and all other authors have indicated they have no financial relationships relevant to this article to disclose.

FUNDING: This research was supported in part by a grant to the University of Pittsburgh from the National Institute on Deafness and Other Communication Disorders (1K01DC012332-01A1) to Dr Kontos. Funded by the National Institutes of Health (NIH).

POTENTIAL CONFLICT OF INTEREST: Dr Collins is founder and board member of ImPACT Applications, Inc; Dr Schatz is a member of ImPACT Applications, Inc. scientific advisory board; and the other authors have indicated they have no potential conflicts of interest to disclose.

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Pediatrics; originally published online August 29, 2016;
DOI: 10.1542/peds.2016-0910