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Received, October 14, 2008.
Accepted, April 1, 2009.

EFFECTS OF A SYMPTOM-FREE WAITING PERIOD ON CLINICAL OUTCOME AND RISK OF REINJURY AFTER SPORT-RELATED CONCUSSION

OBJECTIVE: This study is the first to investigate the influence of a symptom-free waiting period (SFWP) on clinical outcome and risk of repeat injury after sport-related concussion.

METHODS: This was a prospective, nonrandomized study of 16 624 player seasons from 1999 to 2004, including a cohort of 635 concussed high school and college athletes grouped on the basis of an SFWP or no SFWP observed after their concussion. Clinical outcome in symptoms, cognitive functioning, and postural stability 45 and 90 days postinjury was compared with preinjury baseline. Data on SFWP and same-season repeat concussion were recorded.

RESULTS: An SFWP was observed in 60.3% of cases. There were no significant differences between the SFWP and no SFWP groups in acute injury characteristics or clinical outcome with respect to symptom recovery or postinjury performance on formal neuropsychological and balance testing. Most repeat concussions (79.2%) occurred within 10 days of the initial injury. The rate of repeat concussion was actually higher in the SFWP group (6.49%) than the no SFWP group (0.90%) ($P < 0.005$), but the repeat concussion subgroup's SFWP was 2.82 days shorter (95% confidence interval, 0.61–5.03; $P < 0.01$) and these athletes resumed participation 3.55 days sooner (95% confidence interval, 0.06–7.04; $P < 0.05$) than those in the SFWP group in which there was no repeat concussion.

CONCLUSION: Our findings suggest that an SFWP did not intrinsically influence clinical recovery or reduce risk of a repeat concussion. The overall risk of same-season repeat concussion seems to be relatively low, but there may be a period of vulnerability that increases risk of repeat concussion during the first 7 to 10 days postinjury. Further study is required to investigate this preliminary finding and help determine whether this risk can be reduced further with specific injury-management strategies.

KEY WORDS: Brain injury, Concussion, Neuropsychological tests, Sports injuries

Neurosurgery 65:876–883, 2009 DOI: 10.1227/01.NEU.0000350155.89800.00 www.neurosurgery-online.com

Several prospective studies have recently clarified the expected course of recovery in symptoms, cognitive dysfunction, and other abnormalities observed in athletes after sport-related concussion (3, 6, 12, 15, 16, 20). In the vast majority of cases, a single concussion seems to be a relatively benign neurological event, followed by a rapid and complete recovery within several days (3, 7, 19, 20, 24, 25). In some cases, however, recovery and outcome can be complicated when an athlete experiences multiple concussions over a short timeframe. The main risks associated with repeat concussion are thought to be 2-fold: 1) slowed clinical recovery characterized by persistent symptoms or functional impairments, and 2) extremely rare instances of death or severe, permanent disability associated with delayed cerebral swelling (i.e., "second impact syndrome"). The pathophysiology of delayed cerebral swelling remains the subject of great debate in the sports medicine and scientific

ABBREVIATIONS: BESS, Balance Error Scoring System; **CI**, confidence interval; **GSC**, Graded Symptom Checklist; **SAC**, Standardized Assessment of Concussion; **SFWP**, symptom-free waiting period

communities, because it is unclear whether closely spaced injuries are the true underlying mechanism (5, 14, 21, 22, 28). A large prospective study recently suggested that an athlete's risk of repeat concussion is increased within the first several days after an initial concussion (12).

Theoretical assumptions that the brain remains in a metabolically challenged (and, therefore, vulnerable) state for some period of time after concussion have led to the lone constant across all guidelines for clinical management of sport-related concussion: that no athlete should return to participation until completely symptom free (1, 4, 13, 14, 23). Presumably based on the assumption that this window of cerebral vulnerability persists beyond the point of observable clinical recovery (10, 29), most guidelines take this recommendation a step further in requiring that athletes resume participation only after being completely symptom free for several days. The prescribed length of this symptom-free waiting period (SFWP), however, varies across respective guidelines, all of which are based on expert consensus but not tested by scientific methods. Moreover, the SFWP approach to injury management in sports medicine is largely unique to concussion, and in practice, does not seem to be universally embraced by clinicians or athletes (8). The current study is the first to prospectively investigate the extent to which an SFWP was actually implemented by clinicians in the management of sport-related concussion, as well as the association of an SFWP with clinical outcome and risk of repeat concussion in a large sample of high school and college athletes. In keeping with the prevailing theory that a period of cerebral vulnerability exists after concussion, our hypothesis was that observance of an SFWP would improve clinical outcome and reduce the risk of repeat concussion.

PATIENTS AND METHODS

Study Cohort

This study combined data sets from 3 parallel, multicenter studies investigating the effects of sport-related concussion. Across the 3 studies, 16 624 player-seasons were investigated from 1999 to 2004. The current investigation was focused on the 635 athletes (3.82% of player seasons) who sustained a concussion during the combined studies. Please see the notes section of Table 1 for more information on each independent study and sample characteristics (e.g., sex, age, level of play, and sport). The principal investigators for all 3 studies secured approval from the Institutional Review Board for protection of human research subjects at their host institutions. Written informed consent was obtained from all participants (or parent/guardian) before enrollment in the study.

Study Design

All players underwent a preseason baseline evaluation on a battery of concussion assessment measures. Injured subjects were identified and enrolled in the study protocol by a team physician or certified athletic trainer present on the sideline during an athletic contest or practice. *Concussion* was defined according to the American Academy of Neurology Guideline for Management of Sports Concussion, which was the most widely accepted definition at the time these studies were initiated (i.e., "a trauma-induced alteration in mental status that may or may not involve loss of consciousness") (13, 26).

TABLE 1. Statistics for duration of symptoms, symptom-free waiting period, and total time lost after concussion[a]

	NCAA (n = 187)	CPI (n = 367)	Project Sideline (n = 81)	Total (n = 635)
Duration of symptoms (d)	3.42 (4.2)	4.61 (5.67)	4.16 (4.47)	4.20 (3.80–4.60)
SFWP (d)	3.25 (9.97)	3.28 (13.13)	2.62 (6.67)	3.21 (2.33–4.09)
Time lost from competition (d)	6.62 (11.4)	7.95 (15.57)	6.78 (6.05)	7.41 (6.39–8.43)

[a] NCAA, National Collegiate Athletic Association; CPI, Concussion Prevention Initiative; SFWP, symptom-free waiting period. Data are mean (standard deviation [SD]) or mean (95% confidence interval). The NCAA Concussion Study (4251 college player seasons studied) was sponsored by the NCAA; the CPI Study (9094 high school and college player seasons) was sponsored by the National Centers for Injury Prevention and Control at the Centers for Disease Control and Prevention, and coordinated out of the Injury Prevention Research Center at the University of North Carolina at Chapel Hill; and Project Sideline (3279 high school player seasons) studied high school athletes in suburban Milwaukee, WI. The athletes from the total injured sample averaged 17.49 (1.62 SD) years of age, 10.14 (1.06 SD) years of education, and 6.72 (2.86 SD) years of organized participation in the sport being studied. The sample was 88.5% male; there were 327 high school and 308 college athletes in the concussion sample. Most concussions studied occurred in football (80%), followed by soccer (13%), lacrosse (6%), and hockey (1%). One-third of athletes (33.5%) reported a previous concussion, including 6.3% with 2 and 3.1% with 3 or more previous concussions.

The Graded Symptom Checklist (GSC), Balance Error Scoring System (BESS), Standardized Assessment of Concussion (SAC), and a neuropsychological test battery were used to assess postconcussive symptoms, postural stability, and cognitive functioning. Several studies on the effects of sport-related concussion have demonstrated the reliability and accuracy of these measures in correctly classifying injured and noninjured patients after sport-related concussion (2, 6, 11, 15, 18–20). The athletes were tested on the GSC, SAC, and BESS on the sideline immediately after injury, 2 to 3 hours later, and again on several days during the first week postinjury. Neuropsychological testing was administered 1 to 2 days and 1 week postinjury. All measures were then readministered 45 days (Project Sideline) or 90 days postinjury (National Collegiate Athletic Association Concussion Study, Concussion Prevention Initiative Study), the results of which are the main focus of this study on clinical outcome. Alternate forms of all cognitive outcome measures were used to reduce practice effects over repeated administrations.

Two standardized methods were used to determine the point at which athletes achieved complete symptom recovery. First, clinicians used a standardized injury tracking system (Concussion Index) to record detailed information on acute injury characteristics (e.g., unconsciousness, amnesia), recovery time course, SFWP, incidence of repeat concussion, and other aspects of clinical management. Within this tracking system, clinicians were required to record the date on which they thought, based on their overall clinical examination and impression, that the athlete demonstrated a complete resolution of symptoms. This methodology was cross-validated using an empirically derived method that classified an athlete to be symptom free on the date that the GSC total score returned to the player's preinjury baseline score. The empirically derived and clinician impression measures of complete symptom recovery yielded highly consistent results. In the relatively small number of discrepancies (3.74% of all patients) between the 2 methods that changed the assignment of subjects on the study's main independent variable (i.e., SFWP or no SFWP group), the more conservative method (i.e., lengthier estimate of complete recovery) was used.

TABLE 2. Distribution of symptom-free waiting period duration[a]

Duration of SFWP	NCAA % (n)	CPI % (n)	Project Sideline % (n)	Total % (n)
None	41.6 (67)	40.2 (130)	33.3 (26)	39.7 (223)
≤1 d	18.0 (29)	13.9 (45)	11.5 (9)	14.8 (83)
>1 d, <7 d	23.0 (37)	32.8 (106)	39.7 (31)	30.9 (174)
>7 d	17.4 (28)	13.0 (42)	15.4 (12)	14.6 (82)

[a] SFWP, symptom-free waiting period; NCAA, National Collegiate Athletic Association; CPI, Concussion Prevention Initiative.

The design for each of the 3 studies varied slightly. The National Collegiate Athletic Association Concussion Study and Concussion Prevention Initiative Study both involved a multiple arm design stratified based on the intensity of the assessment protocol, from 1 of the following: 1) routine clinical examination plus the GSC, 2) use of a brief screening battery (GSC, SAC, and BESS), or 3) brief screening battery plus neuropsychological test battery. Participating institutions were randomly assigned to a specific arm of the study, so all injured athletes from that institution underwent the same assessment protocol. Project Sideline was a single group design in which all assessment instruments were used for all patients.

Statistical Analysis

Because preliminary analyses demonstrated the consistency of findings across the 3 studies, we restricted statistical analysis to the combined study sample. Cases with missing data that precluded computation of the SFWP variable or measurement of the study's main outcome variables were excluded from analysis. In total, 562 cases (88.5% of the total sample) were available for analysis. There were no statistically significant differences between those cases retained and eliminated from analysis on the study's main variables (e.g., acute injury characteristics, duration of symptoms, clinical outcome measures).

Descriptive statistics were generated on the course of recovery by category, total duration of symptoms, time lost from competition, and duration of the SFWP. SFWP was computed based on the total time lost from sports participation (consecutive days) minus the total duration of symptoms in each case.

Independent group *t* tests and χ^2 analyses were conducted to compare those athletes who observed (SFWP group) and did not observe an SFWP (no SFWP group) with respect to acute injury severity (e.g., frequency of unconsciousness, amnesia, and acute GSC and SAC scores), as well as total duration of symptoms, SFWP, and time lost from competition. To control for baseline performance and to stay in keeping with more advanced methods for statistically measuring recovery after concussion, the same analyses were then conducted by comparing the SFWP and no SFWP groups in terms of change from baseline to day 45 of 90 on the clinical outcome measures. Using baseline data from the large normative sample of athletes (n = 2320), 6 main variables derived from the neuropsychological test battery (see listed with Table 4) were scaled separately and the sum of the scaled scores was scaled to a global index score (mean, 100; standard deviation, 15) using the same standardized method validated by other well-established neuropsychological test batteries (27, 30, 31). Scaling tables derived from this large normative baseline sample were used to calculate global neuropsychological test scores for each subject in the present study, at each assessment point.

TABLE 3. Acute injury characteristics, duration of symptoms, symptom-free waiting period, and total time lost from competition for subjects with and without a symptom-free waiting period[a]

	No SFWP observed[b]	SFWP observed[b]
Loss of consciousness (%)	7.2	10.8
Posttraumatic amnesia (%)	22.9	27.1
Retrograde amnesia (%)	15.7	18.6
Postinjury		
GSC[c]	21.39 (18.84–23.94)	20.63 (18.85–22.41)
SAC[d]	23.37 (22.49–24.25)	23.17 (22.28–24.06)
Postgame		
GSC	17.97 (15.61–20.33)	15.96 (14.01–17.91)
SAC	25.15 (24.52–25.78)	24.89 (24.27–25.51)

[a] SFWP, symptom-free waiting period; GSC, Graded Symptom Checklist; SAC, Standardized Assessment of Concussion.Data are mean (95% confidence interval) unless otherwise noted.
[b] No statistically significant group differences.
[c] Higher scores indicate more severe symptoms on the GSC.
[d] Lower scores indicate more severe cognitive dysfunction on the SAC.

χ^2 statistics were generated to compare the SFWP and no SFWP groups on the frequency of repeat concussion during the same season. Additionally, descriptive statistics were generated for those patients who sustained a repeat concussion in the same season, which were analyzed and compared with those patients who did not sustain a repeat concussion.

RESULTS

Across the 3 studies, 85.4% of injured patients reported a full symptom recovery in less than 1 week, including 21.1% who reportedly recovered within the first day. Only 2.7% of patients reported symptoms beyond 1 month postinjury.

Table 1 provides statistics on mean duration of symptoms, SFWP, and total time lost from competition.

An SFWP of any length was observed for 60.3% of patients, including 14.6% who had an SFWP period of 7 days or more (Table 2). There were no differences between the SFWP and no SFWP groups in demographics (e.g., age, years of education) or baseline performance on the concussion assessment measures (GSC, SAC, neuropsychological test battery).

Acute injury severity was similar in the no SFWP and SFWP groups. There were no statistically significant differences between the 2 groups in duration of symptoms, performance on the GSC and SAC immediately or 2 to 3 hours after concussion, or the frequency of unconsciousness and posttraumatic amnesia (Table 3).

Inherently, patients in the SFWP group had a significantly longer waiting period than those in the no SFWP group, who returned to play an average of 1.22 days (95% confidence interval [CI], −0.89 to −1.55) before reaching a full symptom resolution (mean difference, 7.10 days; 95% CI, 5.67–8.53; $P < 0.001$). Overall, participants in the SFWP group were withheld from competition significantly longer than those in the no

TABLE 4. Mean change from baseline to day 45 of 90 on clinical outcome measures for symptom-free waiting period and no symptom-free waiting period groups[a]

Outcome measure	No SFWP group[b]	SFWP group[b]
GSC	–2.36 (–3.39 to –1.33)	–2.49 (–3.28 to –1.70)
SAC	1.13 (0.65 to 1.61)	1.16 (0.81 to 1.51)
BESS	–2.68 (–4.33 to –1.03)	–2.72 (–3.93 to –1.51)
Global Neuropsychological Test Score	11.31 (7.53 to 15.09)	12.32 (8.46 to 16.18)

[a] SFWP, symptom-free waiting period; GSC, Graded Symptom Checklist; SAC, Standardized Assessment of Concussion; BESS, Balance Error Scoring System. Data are mean (confidence interval). Negative change score indicates reduction in symptoms on GSC and improved performance on BESS; positive change scores indicate improved performance on SAC and Global Neuropsychological Test Score. The Global Neuropsychological Test Score was derived from standardized transformation of scores on the Hopkins Verbal Learning Test, Trail Making Test Part B, Symbol Digit Modalities Test, Stroop Color Word Test, and Controlled Oral Word Association Test.
[b] No group differences were statistically significant.

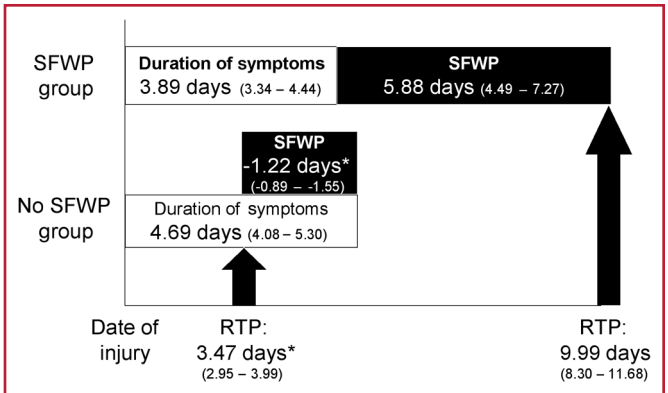

FIGURE 1. *Total duration of symptoms, symptom-free waiting period (SFWP), and time to return to play (RTP) for the SFWP and no SFWP groups.*

SFWP group (mean difference, 6.52 days; 95% CI, 4.74–8.30; $P < 0.001$) (Fig. 1).

Clinical Outcome

There were no statistically significant differences between the SFWP and no SFWP groups in mean change from baseline to day 45 or 90 postinjury on the GSC, BESS, SAC, and global neuropsychological test scores (Table 4).

SFWP and Repeat Concussion

Overall, 24 patients experienced a repeat concussion in the same sports season (3.8% of concussed patients, 0.14% of total sample). These were all male football players (college, n = 14; high school, n = 10). The average interval between first and repeat concussion was 12.75 days (95% CI, 5.41–20.09); 70.8% of repeat concussions occurred within the first 7 days of initial injury and 79.2% were within the first 10 days. The average duration of symptoms after first injury was 3.24 days (95% confidence interval [CI], 1.86–4.62) in those patients who experienced a repeat concussion. In the repeat concussion subgroup, 91.7% returned to competition within 1 week of their first injury, compared with 59.3% of those with no subsequent injury ($\chi^2 = 9.86$; $P < 0.005$).

The rate of repeat concussion in the same season was actually higher in athletes who had observed an SFWP (6.49%) after their initial concussion than in those who had no SFWP (0.90%) ($\chi^2 = 10.33$; $P < 0.005$). Ninety-one percent of patients who experienced a repeat concussion had observed an SFWP after their first concussion (mean duration, 2.96 days; 95% CI, 1.33–4.29). There was no difference in the amount of time between preseason baseline testing and in-season date of first concussion for the SFWP and no SFWP groups.

Within the SFWP group alone, there were no statistically significant differences in the average duration of symptoms in those who experienced a repeat concussion and those who did not (mean difference, 0.73 days; 95% CI, −0.82 to 2.28; $P = 0.37$). There were also no significant group differences in acute injury severity (e.g., measured by the GSC and SAC immediately and 2 to 3 hours postinjury). The repeat concussion subgroup did, however, have a significantly shorter SFWP (mean difference, 2.82 days; 95% CI, 0.61–5.03; $P < 0.01$) and shorter total time withheld from competition (mean difference, 3.55 days; 95% CI, 0.06–7.04; $P < 0.05$) than the SFWP group in which patients did not have a repeat concussion (Fig. 2). There were no statistically significant differences between those patients with and without a repeat concussion in mean change from baseline to day 45 or 90 postinjury on the main outcome measures (Fig. 3).

DISCUSSION

This multicenter, prospective study produced data from the largest sample of athletes with sport-related concussion reported in the literature, and this study is the first to investigate the longstanding assumption that an SFWP affects clinical outcome and reduces the risk of repeat injury after sport-related concussion. Our findings suggest that the incidence of

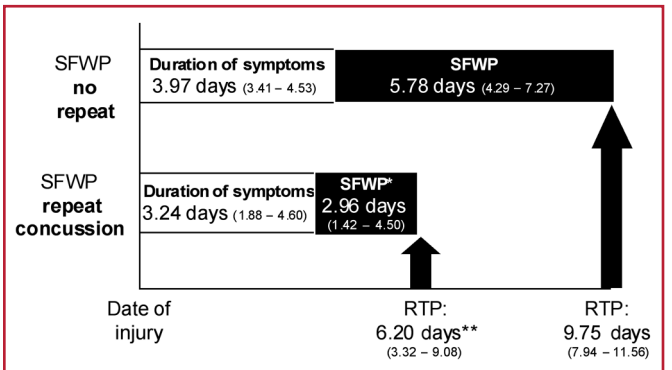

FIGURE 2. *Total duration of symptoms, symptom-free waiting period (SFWP), and time until return to play (RTP) for athletes with and without repeat concussion.*

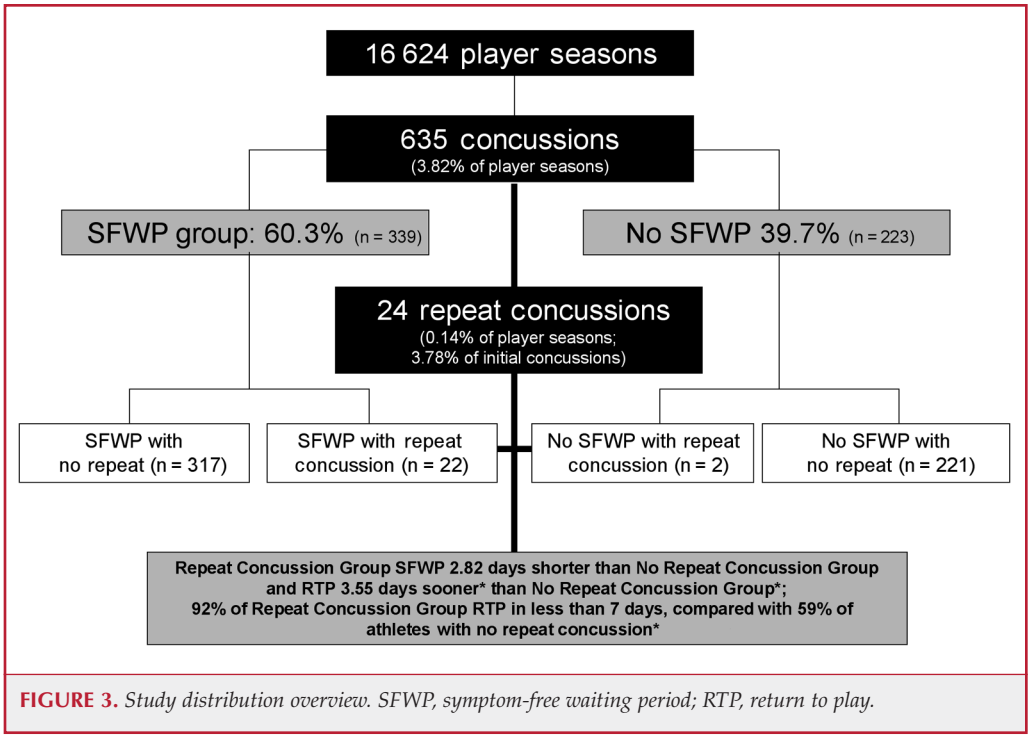

FIGURE 3. *Study distribution overview. SFWP, symptom-free waiting period; RTP, return to play.*

repeat concussion in the same sports season is very low and that observation of an SFWP did not intrinsically influence clinical recovery or reduce the risk of a repeat concussion in the same sports season.

Despite several years of conceptual agreement across sport-concussion management guidelines on the importance of an SFWP, this extended recovery time was observed in only 60% of cases in the current study. Only 15% of athletes observed an SFWP of 7 days or more, as prescribed by several concussion management guidelines. When an SFWP was observed, the average duration was less than 6 days, whereas athletes with no SFWP actually returned to competition an average of 1 to 2 days before full resolution of their symptoms.

Our findings on clinical recovery closely parallel results from earlier studies, and were therefore not unexpected (3, 7, 19, 20, 24, 25). Overall, less than 15% of injured athletes required more than 1 week to achieve full recovery, and less than 3% experienced symptoms beyond 1 month. A unique contribution from the current study, however, is the finding that this rapid recovery from sport-related concussion occurs in the overwhelming majority of cases, regardless of whether an SFWP is observed. Athletes who had no SFWP returned to competition an average of nearly 7 days sooner than those in the SFWP group, but did not demonstrate any persistent post-concussive symptoms or residual impairments in cognitive functioning or postural stability several weeks postinjury relative to athletes who observed an SFWP.

Our data are also consistent with the theoretical concept suggesting that there is a 7- to 10-day window of cerebral vulnerability in the order of several days after concussion (9, 12), during which the risks of repeat concussion are greatest, because nearly 80% of repeat concussions occurred within 10 days after initial injury. The overall number of repeat concussions (n = 24) in the current study was low, however, which renders this finding tentative. The low incidence of repeat concussion in our study (3.78% of athletes with initial concussion, 0.14% of total sample exposed) is also consistent with previous reports from prospective studies (12, 17). Whereas the overall risk of repeat concussion in the same season was equivalent to the baseline risk of initial concussion (3.82%), repeat concussions were far more common during the first 10 days postinjury than beyond the 10-day point (19 of 24 repeat concussions occurred within the first 10 days of initial injury).

To our knowledge, there is only 1 other prospective study of same-season repeat concussion that examined the interval between first and repeat concussion (18). In that study, 2.6% of college football players who had a concussion later sustained a same-season repeat concussion. There were only 5 repeat concussions studied, with an average interinjury interval of 33 days (range, 14–70 days). Same-season repeat concussions would therefore seem to be relatively rare, with an incidence that is not much different from the base rate of initial concussion, but there may be an increased risk of repeat concussion during the first 7 to 10 days after concussion. This finding requires further study.

Our most unexpected and perplexing finding was that the incidence of repeat concussion in the same sports season was actually higher among athletes who observed an SFWP before returning to competition after their concussion, despite the fact that many athletes in the no SFWP group actually returned to play while still symptomatic. It is noteworthy, however, that those athletes who experienced a repeat concussion on average had an SFWP 3 days shorter and returned to competition nearly 4 days sooner than others who observed an SFWP with no subsequent concussion. Also, the repeat concussion subgroup (92%) was nearly twice as likely as the no repeat group (59%) to return to competition within the first week after injury, despite equivalent duration of symptoms and acute injury characteristics in the 2 groups.

Is it unclear why repeat concussion was observed almost exclusively in the group of athletes for whom an SFWP was observed. It seems highly unlikely, of course, that returning to

play while still symptomatic could be protective against repeat concussion. There were no differences that we could identify, however, between the 2 groups in acute injury characteristics (e.g., unconsciousness, amnesia, symptom severity, degree of cognitive dysfunction) that might have influenced team medical personnel to adopt a more cautious approach for the players in the SFWP group. It is conceivable that some combination of factors not easily identified on an objective basis (e.g., player history, individual playing style) led clinicians to determine that certain athletes might be at increased risk of repeat concussion and therefore withheld them from play for a longer period. Merely establishing an SFWP did not, however, protect these athletes from repeat concussion. The larger group of athletes initially considered at risk were protected from risk of repeat concussion while observing a significantly lengthier SFWP and period of no exposure while withheld from competition for the first 10 days after concussion. It was when the SFWP was shortened and players initially classified in that same at-risk group were returned to play several days sooner, that the risk of repeat concussion was greatest. It is conceivable that if the SFWP had been somewhat longer for these athletes, some of the repeat concussions would have been avoided, but this also remains speculative. To ultimately clarify the basis for the current findings, further investigation is required to determine what criteria clinicians rely on most when deciding observance of an SFWP and an athlete's eventual readiness to return to competition after concussion.

In addition to the obvious clinical implications, our findings have relevance to our understanding of delayed cerebral swelling. Although several cases of catastrophic outcome after a sport-related concussion have been reported, it is extraordinarily rare and the precise etiology remains unclear. The fact that nearly 40% of athletes in this study returned to play before they were symptom free (on average, 1.2 days before symptom resolution), but experienced no severe adverse events, suggests that this rare catastrophic outcome might not result from the mechanistic effects of 2 closely spaced injuries, but is more likely the result of an unusual physiological vulnerability (e.g., an idiosyncratic cerebrovascular autoregulation defect, cellular disruption, or other factors mediating an unusual vulnerability to minor brain trauma), independent of the characteristics, multiplicity, or timing of their concussions (21).

Several limitations to the current study warrant acknowledgment, the most significant of which is that this was an observational study and not a randomized controlled trial. Given the existence of published clinical practice guidelines prescribing the SFWP and expert consensus on the assumed clinical benefit of the SFWP before this study, it is unlikely that a study with a random assignment of an SFWP (versus no SFWP) could have been ethically feasible. This study represents the largest prospectively studied sample of sport-related concussion accumulated to date, and these data may be the most informative that we can expect to obtain on the topic. Despite this large sample of athletes exposed to injury risk, the sample of repeat concussions in this study was very small and highly consistent across all 3 studies. Sizable resources would be required to mount a controlled study of sufficient size to yield a large enough subsample of repeat concussions to explore the effects of management strategy (presuming that one could obtain Institutional Review Board approval for a randomized study of this nature). For instance, a study of 70 000 athletes would be required to accrue 100 repeat concussions within the same sports season based on the rate in our study and the only other prospective study on the rate of same-season repeat concussion (17).

Another potential limitation is that symptom recovery in this study was largely based on self-report, and it has been suggested that athletes may be motivated to deny or minimize their symptoms in order to return to competition. If anything, however, this would suggest that a higher percentage of athletes were returned to play while still symptomatic than we have reported, which would not seem likely to significantly alter our overall findings. In addition, the other main outcome measures in the study (balance testing, neurocognitive testing) are performance-based and provide a more objective indication of recovery, especially when compared with each individual player's preinjury baseline score. Missing data eliminated approximately 10% of cases from study. However, separate analysis indicated that the eliminated cases did not differ in any systematic way from the remaining subjects. Finally, this study does not address the potential long-term consequences of multiple concussions, which constitutes a separate focus of concern.

CONCLUSION

Findings from the current study suggest that the incidence of repeat concussion in the same sports season is relatively low, and that adherence to an SFWP did not intrinsically influence short-term clinical outcome or reduce the risk of repeat injury after sport-related concussion. These data also provide tentative support for the theory that there is a window of increased vulnerability during the first 7 to 10 days after concussion, and suggest that the risk of repeat concussion may be more closely associated with that initial period of vulnerability than with apparent symptom resolution or the observance of an SFWP. These findings indicate the need for conservative injury management and return to play decision making by clinicians during the first 7 to 10 days after initial sport-related concussion, but further study is required to more precisely quantify the true risks associated with sport-related concussion, and the extent to which these risks can be modified by an SFWP or other preventative injury management strategies.

Disclosure

This research was funded in part by the National Collegiate Athletic Association, the National Operating Committee on Standards for Athletic Equipment, Waukesha Memorial Hospital Foundation, National Academy of psychology, National Federation of State High School Associations, National Football League Charities, Green Bay Packers Foundation, Waukesha Service Club, and the Medical College of Wisconsin General Clinical Research Center (M01 RR00058). Major funding came from the National Centers for Injury Prevention and Control (for the Concussion Prevention Initiative Study, and the University of North

Carolina Injury Prevention Research Center contributed to the execution and success of this project. Michael McCrea, Ph.D., had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis. None of the authors has any conflict of interest to declare with respect to this study, nor personal financial or institutional interest in any of the drugs, materials, or devices described in the article. The funding sponsors did not have a role in the design or execution of the study beyond funding, and had no involvement in the preparation of the manuscript.

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Acknowledgments

We thank the certified athletic trainers, team physicians, and student athletes from the high schools and universities that participated in this study.

COMMENTS

In this prospective study of more than 16 600 high school and college football players, 635 players sustained a concussion, and, of these, 24 sustained a second concussion. Notably, in 79% of these 24 players, the second concussion occurred within 10 days of the initial concussion and occurred at a much higher rate (6.5% versus 1%) in the group of players who observed a symptom-free waiting period (SFWP) than in the group who did not observe an SFWP. As the authors indicate, this important and somewhat surprising finding suggests that the absolute time for return to play is a more important parameter than concussion-related symptoms in determining the window of vulnerability to a second concussion. Furthermore, it suggests that the cerebral metabolic pathophysiology that underlies this vulnerability has a relatively consistent timeline that largely resolves within 10 days of impact in most individuals. Until further data are available, the authors' recommendation of a minimum waiting period of 10 days postconcussion before return to athletic play appears to be prudent, simple, and safe.

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The authors investigate the widespread belief that mandating an SFWP reduces the risk of repeat injury after sports-related concussion. Curiously, the incidence of repeat concussion in the same season was increased in athletes who underwent an SFWP before returning to competition. However, SFWP athletes who experienced a repeat concussion had a significantly shorter SFWP (almost 3 days shorter) and earlier return to competition (3.5 days sooner) than those who under-

went an SFWP without subsequent concussion. The majority of repeat concussions occurred within 10 days of the initial injury. The authors conclude that the simple use of an SFWP, in and of itself, did not influence clinical recovery or reduce the risk of a repeat concussion in the same season. Instead, the time between injury and return to competition may have been more important, and it may be more appropriate for trainers and team physicians to wait for a defined period before allowing return to play after a concussion, instead of waiting only for symptom resolution with or without a brief SFWP.

It is also noteworthy that almost 40% of concussed players in this study returned to play before they were symptom-free (on average, 1.2 days before symptom resolution) yet experienced no major adverse events. As the authors discuss, this finding suggests that the second-impact syndrome may have more to do with an aberrant physiological response than to the time interval between injuries.

Within the limits of study methodology, the authors could not identify any inherent differences in baseline characteristics between the SFWP and non-SFWP groups. Perhaps trainers and team physicians had subtle reasons to delay return to play in those athletes who ended up in the SFWP group, but the answers to such questions await further investigation.

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McCrea et al. report on a cohort of 635 high school and collegiate athletes who sustained concussions during the years 1999–2004; they focus on the contribution of an SFWP and the likelihood of recurrent injury. Although 60% of the injured players had an SFWP, this group actually had a higher risk of recurrent concussion. This counter-intuitive finding should be considered within the context of several limitations of the study. First, the number of second concussions was low, at only 24 athletes. In addition, the data were self-reported in nature and observational, as the authors note. Also, the potential for the SFWP to affect the potential for cumulative brain injury cannot be fully assessed in a contemporaneous study.

The findings nevertheless highlight some important features of this population. It is not universal that an SFWP is observed across the sports medicine community. The occurrence of second concussion is unusual within the same season, and some players were still symptomatic when allowed to return to play. The authors believe that there may be a period of increased susceptibility for repeat injury within the 7 to 10 days after a concussion. Rather than assume that this means that a management style that minimizes an SFWP is safe, it likely affirms that other factors may be involved with an obvious, currently deleterious outcome, such as acute cerebral edema (second impact syndrome) or noticeable diminution in playing ability or in mental functioning. The harmful effects of second concussion more likely are related to factors such as genetic predisposition, the kinetic energy or biomechanical factors of each particular impact (neck strength, being "blind-sided," *g* forces, etc.), multiple blows within the same contest (e.g., boxing), style of play, severity (grading) of each concussion, and others.

The authors' detailed work and collection of extensive data that should add to our understanding of the myriad features of concussion. This study is provocative in encouraging us to continue to analyze all aspects of traditional management strategy, and it affirms the importance of individualization of the care and decision-making process for these athletes. The above being stated, I do not think that we should assume that disregarding an SFWP is advisable or desirable. As I like to emphasize, these patients are the only ones who present for the neurosurgeon's evaluation and recommendation and basically say, "Doctor, I have injured my brain, and it has healed; I now would like to go back and sustain innumerable more brain impacts. Is that fine?"

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Ever since the seminal papers by Cantu in the 1980s, the hallmark of sports concussion management has required a symptom-free period before allowing a return to competition. This tenet is now being challenged with reasonably robust scientific data by McCrea et al. As the authors point out, however, data derived from self-reporting—especially from highly competitive athletes—is always open to question. That, 40% of the time, presumably knowledgeable athletic trainers and sports medicine clinicians, especially those at the National Collegiate Athletic Association level, chose to ignore this basic tenet is alarming, although it was apparently not harmful to the 19 players who experienced a second concussion while still symptomatic.

Although I would agree with the authors that the second-impact syndrome likely represents a highly individualized selective vulnerability, the one constant across all reports of its occurrence is repeat concussion in athletes with ongoing symptoms. Since it remains impossible to prospectively identify such vulnerable athletes, it is difficult to support a non-SFWP policy, in spite of this study's conclusions. This is especially true because the data appear to show a 7- to 10-day period of increased vulnerability to a second concussion.

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FUTURE MEETINGS—CONGRESS OF NEUROLOGICAL SURGEONS

The following are the planned sites and dates for future annual meetings of the Congress of Neurological Surgeons:

2010	San Francisco, CA	October 23–28
2011	Washington, DC	October 1–6
2012	Chicago, IL	September 29–October 4
2013	San Francisco, CA	October 19–24