A Prospective Study of Postconcussive Outcomes After Return to Play in Australian Football

Michael Makdissi,*† MBBS, PhD, Paul McCrory,† MBBS, PhD,
Antony Ugoni,† BSc(Hons), MSc, David Darby,‡ MBBS, PhD, and Peter Brukner,† MBBS
From the †Centre for Health, Exercise and Sports Medicine, University of Melbourne, Parkville, Victoria, Australia, and ‡CogState Ltd, Melbourne, Victoria, Australia

Background: Decisions regarding safe return to play after concussion in sport remain difficult.

Objective: To determine whether a concussed player returned to play using an individual clinical management strategy is at risk of impaired performance or increased risk of injury or concussion.

Study Design: Cohort study; Level of evidence, 3.

Methods: All elite Australian football players were followed for 4 seasons. Players were recruited into the study after sustaining a concussive injury. Outcome measures included performance statistics (disposals per hour match-time), injury rates, and recurrence of concussion on return to play. A subset of players had brief screening cognitive tests performed at baseline and after their concussion. Noninjured players matched for team, position, age, and size were chosen as controls.

Results: A total of 199 concussive injuries were observed in 158 players. Sixty-one concussive injuries were excluded from analysis because of incomplete data (45 players) or presence of concurrent injury (16 players). Of the 138 concussive injuries assessed, 127 players returned to play without missing a game (92%). The remainder of concussed players returned to play after missing a single game (8%). Overall, there was no significant decline in disposal rates in concussed players on return to competition. Furthermore, there were no significant differences in injury rates between concussed and team, position, and game-matched controls. In the subset of players who had completed screening cognitive tests, all had returned to their individual baseline performance before being returned to play.

Conclusion: Return to play decisions based on individual clinical assessment of recovery allows safe and appropriate return to sport following a concussive injury.

Keywords: brain trauma; concussion; Australian football

Sports concussion can be defined as a complex clinical syndrome precipitated by traumatic forces to the brain sustained during participation in sport.[2] The current consensus opinion is that it reflects a nonstructural injury, characterized by a graded set of clinical and cognitive features that are typically short-lived and resolve spontaneously.[20] While the implication is that concussed athletes would be expected to recover uneventfully, a number of potential short- and long-term complications have been described. These include impaired performance and increased risk of injury, acute progressive diffuse cerebral edema,[5] prolonged symptoms[26] or symptoms of depression,[12] and cumulative cognitive deterioration.[11,16] Moreover, it has widely been suggested that the risk of adverse outcomes after sports concussion is greatest when a concussed athlete is returned to play prematurely.[4] Consequently, it is important for treating physicians to ensure that concussed athletes are fully recovered before allowing them to return to play. The main problem in the clinical setting, however, is that there is no single, objective, quantitative criterion to measure recovery after concussive injury.

The criteria by which return to play decisions are made after concussion have long been a contentious area of sports medicine. Although numerous guidelines have been proposed, these are based on limited scientific data.[14] One of the fundamental paradigm shifts of the current Concussion in Sport Group recommendations was to move the concept of return to play from anecdotal injury grading scales and arbitrary exclusion periods to one of individualized assessment using a combination of clinical symptoms and brief cognitive testing.[2,20]

*Address correspondence to Michael Makdissi, MBBS, PhD, Univeristy of Melbourne, Centre for Health, Exercise, and Sports Medicine, Parkville, Victoria, Australia 3010 (e-mail: makdissi@unimelb.edu.au).

No potential conflict of interest declared.

The American Journal of Sports Medicine, Vol. 37, No. 5
DOI: 10.1177/0363546508328118

Although there is extensive literature on cognitive performance after sports concussion, no studies to date have investigated functional outcomes in concussed athletes on their return to play. Therefore, while the current guidelines provide practitioners with expert opinion to help guide the management of concussive injuries, they have yet to be validated.

Professional Australian football has one of the highest rates of concussive brain injury of any team contact sport, with a reported incidence of 3.9 per 1000 player hours.[21] Because of the high frequency of concussive injuries in this sport, during the past 20 years team doctors have used an aggressive return-to-play management strategy based on a combination of clinical symptoms resolution and limited cognitive testing.[21] Therefore, the Concussion in Sport Group guidelines have long been the accepted practice for the management of concussed Australian football players.

The objective of the current study is to determine whether a concussed player returned to play using an individual clinical management strategy is at risk of impaired performance or increased risk of injury or concussion on their return to competition.

METHODS

Participants

All elite professional players participating in the national football competition (Australian Football League, AFL) were followed prospectively for 4 seasons (2000-2003). Players were referred into the study when they had experienced a concussive injury while playing football in an AFL competition. The team doctors at each club, who were present at the time of injury, made the diagnosis of concussion in each case according to standard injury definitions.[2,7] Criteria contributing to the identification of concussed players included symptoms reported by players or signs observed by medical staff after a traumatic injury. Symptoms included (but were not limited to) players reporting feeling dinged, dazed, stunned, woozy, foggy, "head full of cotton wool" or "not quite right" as well as posttraumatic headache, visual disturbance, confusion, memory disturbance, balance disturbance, vertigo, and lightheadedness. Signs included confusion, loss of consciousness, disorientation, memory disturbance, unsteadiness, attention deficit, and personality change.

To ensure complete reporting by team doctors, the integrity of the concussed player dataset was verified with both media injury reports and with information obtained from the independent prospective injury database that records all injuries occurring in the AFL.[23]

Exclusion Criteria

Players were excluded from the analysis if they:

- played no games before their concussive injury (insufficient baseline)
- played no games after their concussive injury (insufficient follow-up; this group included players who returned to a lesser grade competition on their recovery from injury and those who were concussed during the last game of the season)
- were suffering from an unrelated nonconcussive concurrent injury or illness preventing their return to play.

Management of Concussed Players

All AFL teams are cared for by 1 or 2 team doctors (MD trained), who are present at each training session and travel with the team to each game. During the game itself, the team doctors have unrestricted access to the field of play to assess and treat any injured players. All current AFL team doctors have more than 10 years of experience in sports medicine.

The entire group of AFL team doctors are representatives of a group called the AFL Medical Officers Association (AFLMOA). The AFLMOA holds regular meetings, conducts research projects, and provides ongoing education programs for all members. Consequently, AFL team doctors have a relatively standardized approach to the diagnosis and management of common problems such as sports concussion.

The standard AFL approach to return-to-play decisions after concussion involves monitoring of symptom recovery and a limited cognitive assessment, using either paper and pencil or computerized test batteries. The uniform management strategies employed by AFL medical officers are based on longstanding research and education programs dating from the mid-1980s.[17,21] Furthermore, this clinical approach to return to play decisions after concussive injury mirrors the current recommendations of the Concussion in Sport Group.[2,20] During the current study, team doctors were not specifically instructed on guidelines for return to play, nor was there an AFL mandate that all doctors adhere to it.

The matches in Australian Football are played on consecutive weeks between the months of March and September, with games being separated by 6 to 9 days. The time taken to return to play after a concussive injury was used as a surrogate marker of clinical recovery and calculated in terms of games missed. In each case, the return-to-play decision was made by the team doctor based on previously described clinical strategies. This study did not attempt to influence these decisions.

Outcome Measures

Cognitive deficits such as impaired speed of information processing, memory disturbance, and slowed reaction time have been reported after concussive injury.[3,17,19] A concussed player with such deficits may be impaired in their ability to adjust to the complex demands of a collision sport such as Australian football. Therefore, players who have not fully recovered from a previous concussive injury would be expected to be impaired in their performance and, as a result, be predisposed to higher injuries rates on their return to competition. Consequently, the primary outcome measures chosen for this study included performance statistics, injury rates, and recurrence of concussion.

Once a player was identified as having sustained a concussive injury, data on all outcome measures were collected for 3 AFL games preceding injury and the player's first 3 consecutive AFL games after injury.

Analyses were conducted using 1 or 3 pre- and postinjury game performance parameters. The data from the average of 3 games pre- and postconcussion were tested against that obtained from a single game. The purpose of this assessment was to determine the effect of normally observed game-to-game variance in performance on the results and subsequently take into account confounding factors such as environmental conditions, opponents, and roles played during different games.

For each concussed player, control players were selected from the noninjured playing population of the same team playing in the same games. Controls were matched for playing position, age, and size. These factors were chosen as they may have a significant impact on performance statistics, occurrence of injuries, and rate of recovery after concussion. All outcome measures were assessed in the control players and compared to those in the concussed group.

"Disposals" is a common term used in Australian football to describe a player's movement of the ball by hand (handball) or foot (kick) to facilitate their team scoring goals. The number of disposals that a player has during a match is commonly used as an objective measure of the player's performance. The data are collected by 4 independent statisticians during each AFL game and are verified by video analysis. To increase the accuracy of these figures, the time involvement during a game (recorded in percentage of time spent on the playing field) was obtained for each concussed player from the official interchange records kept during each game. The standard match time for a game of Australian football is 80 minutes (1.33 hours). This excludes time lost for stoppages in play.[24] The player's match time for each game was calculated by multiplying the percentage of time the player spent on the field by 1.33 hours (total match time). The total number of player disposals recorded during each game was then divided by the player's individual match-time for the game to obtain disposals per hour match time (ie, disposal rate).

For the cohort of identified concussed players, the AFL injury database was accessed, and any injuries occurring in games on return to competition were recorded. Injury rates observed in the concussed players on their return to competition were compared with the injury rates observed in team-, game-, and position-matched control players. All injury rates were expressed as numbers of injuries per 100 games (95% confidence intervals [CI]).

For the purpose of this study, recurrence of concussion was defined as a further concussive injury occurring on the player's return to competition (whether it resulted in games missed or not).

Cognitive recovery was also included as a secondary outcome measure during the study. Of the overall player cohort, a nested group had brief cognitive test data available to confirm cognitive recovery. These players were members of teams that had volunteered to participate in a large cohort study assessing the role of neuropsychological testing in concussion management.[18] In all players, a standard assessment was performed, which included the Digit Symbol Substitution Test (DSST)[27] and the Trail Making Test-Part B (TMT-B).[1]

The outcome measures used for the current study have been collected in an independent, prospective, and systematic fashion during 15 years in the AFL. Although the team doctors were aware that the study was being conducted, they were unaware of the outcome measures being used.

Statistical Analysis

Power calculations. The calculation of sample size was based on the comparison of 2 independent rates, that is, underlying Poisson distributions. Historical data suggest that on average, footballers accumulate approximately 13 disposals per hour. A 20% decrease in disposal rate on a player's return postinjury was chosen to represent a clinically significant change. Using these figures and a 5% level of significance, it was determined that 54 game hours in both the pre- and postinjury groups would be required to achieve 90% power. This sample size calculation did not take into account the correlated nature of the pre- and postinjury groups, that is, same individuals in both groups, as there were no data to enable any estimate of such a correlation.

Performance statistics. Disposal rates (per hour of match time) were determined for games before and after concussion. A ratio of pre- to postconcussion was then calculated for each player ($Ratio_{Concussed}$) and the average ratio calculated. The CI for this average ratio was determined using the bootstrap technique (with 10 000 bootstrap samples).[8] This was repeated for the control group ($Ratio_{Control}$). A third ratio ($Ratio_{Concussed}$ to $Ratio_{Control}$) was calculated to compare the concussed to the control groups. Again, the bootstrap analysis was used to calculate the CI for this third ratio.

All ratios were expressed as mean change in disposal rate (95% CI), and statistical significance was defined as the exclusion of the value 1.00 within the 95% CI (α level 0.05, 2-tailed test).

Injury rates. Confidence intervals for injury rates (per 100 games) were calculated using the Poisson distribution, and the comparison between the concussed and control groups was made using normal comparisons of incidence.[9]

Cognitive data. The DSST was expressed as the total score in 90 seconds, and the TMT-B was calculated as time (seconds) taken to complete the test to the nearest second.[27] Tests were performed before the player was returned to play and compared to the player's individual preseason baseline score. Mean change and percentage change scores were calculated to assess differences between preseason baseline and postinjury test scores. Paired Student *t* tests were used to investigate the significance of any differences and directional trends between baseline and postconcussion results.

Repeat injuries. When a player experienced a second concussion in the 4-year study period, each episode greater than 3 weeks apart was considered an independent event and analyzed as above.

Approval for the study was granted by the Human Research Ethics Committee of the University of Melbourne. Permission to access injury databases was obtained from the AFL Medical Officers Association.

RESULTS

A total of 199 concussive injuries were observed in 158 players during 4 seasons (total games = 26 640; total player hours = 35 520). One player was concussed 4 times, 8 players were concussed 3 times, and 22 players were concussed 2 times during the study period. The remaining 127 players experienced a single concussive injury. The overall incidence of concussion in the elite population of players during seasons 2000 to 2003 was 5.6 per 1000 hours.

Single-Game Versus 3-Game Analysis

Analysis of the performance statistics (see Table 1) and injury rates demonstrated no differences between using 1 game or 3 games pre- and postinjury. However, when only a single game was used, a larger proportion of the concussed player group was able to be included in the analysis, thereby reducing any potential for selection bias. Subsequently, the remainder of the discussion relates to the dataset where a single game pre- and postconcussion is used.

Excluded Players

A total of 61 concussive injuries were excluded from the analysis. Twenty-two of these players did not play any games before their injury (insufficient baseline), 23 players did not return to senior football after their injury (insufficient follow-up), and 16 concussed players did not return to competition because of concurrent injuries or illness.

Of the 22 players who did not play any games before their concussive injury, 19 returned to play the following week (86%), and 3 missed 1 game. Twenty-one players returned uneventfully. One player was concussed again on his return to play. This player subsequently retired because of persistent headaches.

Of the 23 players with insufficient follow-up, 12 were concussed during the last game of the season, and 11 returned to reserves grade football before their elevation back to the senior team. Three of these players missed a week because of their concussive injury, with the remainder returning without missing a game. None of these players were injured in their first game back.

Of the 16 cases with concurrent injuries, 7 had associated injuries to the face or neck, and 7 had other injuries occurring during their concussive collision (ribs, hamstring, knee, leg, and ankle). Two other players missed a game because of medical illness before their return to senior football.

TABLE 1
Summary of Performance Statistics[a]

	3 Games	Single Game
$Ratio_{Concussed}$	1.04 (0.99-1.10)	1.08 (0.99-1.11)
$Ratio_{Control}$	1.08 (1.02-1.14)	1.23 (1.09-1.43)
$Ratio_{Concussed}$ to $Ratio_{Control}$	1.04 (0.97-1.12)	1.20 (1.03-1.38)

[a]All results are expressed as ratios of disposal rates per hour match time (95% confidence intervals [CI]); $Ratio_{Concussed}$, ratio of disposal rates pre- and postconcussion; $Ratio_{Control}$, ratio of disposal rates in control players; $Ratio_{Concussed}$ to $Ratio_{Control}$, ratio of concussed to control groups; statistical significance is defined as the exclusion of the value 1.00 within the 95% CI (α level 0.05, 2-tailed test).

TABLE 2
Summary of Demographic Data[a]

	Concussed (n = 138)	Control (n = 138)	*P* Value
Age	24.7 (24.0-25.3)	24.6 (24.1-25.2)	.77
BMI	25.2 (25.0-25.4)	25.3 (25.1-25.5)	.60

[a]Results are reported as mean (95% confidence interval). BMI, body mass index (weight [kg]/height [cm^2]).

Included Players

A total of 138 concussive injuries were analyzed in 117 players. One hundred and twenty-seven out of 138 concussed players did not miss a game (92%), and the remaining 11 concussed players missed only 1 game (8%). The demographic data are summarized in Table 2. Overall, concussed and control groups were well matched regarding age and body mass index (BMI).

Performance Statistics

The performance statistics for concussed and control players are summarized in Table 1. The results demonstrate a small deficit in the performance of control players from pre- to postinjury (in both the 3- and single-game analyses). Furthermore, concussed players had slightly higher disposal rates than matched controls on return from injury. These differences were more pronounced in the single-game analysis, largely because of the effect of increased game-to-game variation in performance. Nevertheless, these results demonstrate that the performance of concussed players was not impaired on their return to play following injury.

Injury Rates

Ten players were injured in their first game back after concussion. Eight players experienced injuries to their lower limbs (2 hamstring strains, 2 calf strains, as well as injuries to the thigh, leg, knee, and groin), 1 player experienced a fractured arm, and the other injured his back in a

collision. The nature of these injuries was not significantly different from those observed in the matched-control players or those reported in the overall AFL competition.[23] No cases of second-impact syndrome were observed during the duration of the study.

The injury rates are summarized in Table 3. The overall injury rate on return play following concussion was 7.25 per 100 games (95% CI: 3.48-13.33). This compares to 3.25 per 100 games (95% CI: 1.96-5.07) in team, position, and game-matched controls. Although there was a trend for the concussed players to have more injuries upon return to play, this finding was not significant.

TABLE 3
Injury Rates for Concussed and Control Players in Games on Return to Play[a]

	Number of Injuries	Games	Injury Rate	Ratio
Concussed	10	138	7.25 (3.48-13.33)	2.23 (0.93-5.04)
Controls	19	585	3.25 (1.96-5.07)	

[a]Results are reported as injury rates per 100 games (95% confidence intervals [CI]); a ratio (95% CI) of injury rates in concussed to control players is also provided; statistical significance is defined as the exclusion of the value 1.00 within the 95% CI (α level 0.05, 2-tailed test).

Concussion Recurrence Rates

No player was concussed again in the first game back after injury.

Cognitive Test Results

Digit Symbol Substitution Test and TMT-B results were available for 25 of the 138 concussive injuries analyzed in this study (18.1%). Players in this subgroup did not differ from the main cohort with respect to age, size/body type, and time to return to sport. The results, summarized in Table 4, demonstrate that scores on both the DSST and TMT-B improved significantly from baseline, before players were returned to competition.

TABLE 4
Summary of Cognitive Test Results in a Subgroup of Concussive Injuries[a]

	Mean Change Score (95% CI)	% Change Score	*P* Value
DSST score	4.4 (2.0 to 6.8)	6.6	.002
TMT-B time (sec)	–6.3 (–2.3 to –10.7)	12.8	.011

[a]Mean change score = postinjury score - baseline score; percentage (%) change score = (mean change score/baseline score) × 100%; improvement in performance is reflected by an increase in DSST score and decrease in TMT-B time. CI, confidence interval; DSST, Digit Symbol Substitution Test; TMT-B, Trail Making Test-Part B.

DISCUSSION

This study investigated the short-term functional outcomes after return to play in a large cohort of concussed football players managed according to current consensus guidelines. The results demonstrated that 92% of concussed players returned to competition without missing a game and the remainder returned to play after missing a single game. Overall, there were no detrimental effects observed in performance and no significant increase in injury risk after return to play when compared with matched control players. Furthermore, in the subset of players for whom the cognitive test results were known, there were no persistent deficits in the players' cognitive function.

In the clinical setting, the critical consideration in allowing a player to return to play after concussion is deciding when that player has recovered from his injury. The results of the current study suggest that a comprehensive clinical approach involving careful monitoring of postconcussive symptoms and the use of screening cognitive tests to assess cognitive function postinjury is suitable for monitoring recovery after sports concussion.

The results of the current study demonstrate that 92% of concussed athletes recovered clinically and were able to return to competition within 6 to 9 days of their injury. This is consistent with recovery times following concussive injury reported in other studies, particularly in elite players.[25]

Despite the rapid time to return to sport, analysis of disposal rates showed that the level of performance in concussed players on their return postinjury was not significantly different from their preinjury performance. The current data did, however, demonstrate that when compared with control players, concussed players had a small increase in disposal rates on their return to play. This is most likely a reflection of the data for the control players, which demonstrate a small but significant decrease in performance from pre- to postinjury games. The reasons for these differences are not entirely clear. One possible explanation is that players who suffer from concussive injuries have a more aggressive style of play[10] that is more resistant to other factors that may confound performance, such as the standard of the opposition. Moreover, given that players and matched controls played a similar role in each game, their performance could be expected to be inversely proportional to each other. Therefore, a small increase in disposal rates of one group may be associated with a small reduction in disposal rate in the other group.

Although the results of this study demonstrated no significant differences between the injury rates of both concussed and control groups on return to play after injury, wide confidence intervals were observed in the groups. Part of the problem was that small numbers of injuries were observed in the study cohort. While the study was well powered to detect differences in performance statistics, the low numbers of injuries observed increases the likelihood of a type II error for this component of the data. Another possibility is that the group data hid small

subsets of individuals who had not recovered from their concussive injury but had been returned to play prematurely. This may have been the case for one of the players in the excluded group (insufficient baseline) who experienced a second concussive injury on return to play the following week and subsequently retired because of persistent headaches. The clinical implication of these data is that a conservative return to play approach should be used, particularly when there is doubt regarding the clinical recovery of the athlete after a concussive injury. Moreover, while there is no single direct measure of recovery after concussion, clinical assessment should be multifactorial and include detailed assessment of symptoms, balance, and cognitive function.[20] In the future, new functional imaging modalities may allow a more accurate assessment of recovery after concussion; however, these technologies are still to be evaluated in the setting of sports concussion.[6,13,15]

The incidence of concussion reported in the current study (5.6 per 1000 player hours) is higher than previously reported rates in elite Australian football.[21] One possible reason for the higher incidence of concussion in the current study may relate to a recent evolution of the game, where both the speed of play and size of players have increased significantly in the past decade, particularly at the elite level.[22] A faster game involving bigger and stronger players would be expected to increase the impact force during collisions. Another contributing factor may relate to a more complete reporting of concussive injuries in the current study.

The main strength of the present study lies in the use of a controlled prospective design to examine the outcome of current return to play guidelines for athletes with sports concussion. Furthermore, using the setting of the elite Australian football competition takes advantage of having experienced team doctors with a standard approach to diagnosis and management of concussed players, objective and independent collection of player statistics, and systematic collection of injury data, which already exist in the AFL.

One of the main limitations of this study was that cognitive tests were not available for analysis on all concussed players. In part, this was an inevitable consequence of assessing existing management strategies without any intervention by the study authors.

A further limitation is the use of disposal rates as a surrogate measure of player performance. Although, the disposal rates used in the current study were accurate and objective, they only provide a gross measure for functional outcome. Consideration should be given to the use of sports-specific functional tasks that may provide a more sensitive measure of performance, yet are practical.

Finally, it is important to note that the current data are derived from a cohort of young (aged 16-36 years), male, Australian footballers, and it remains unclear as to whether the results are generalizable to other sports or specific cohorts of athletes. Moreover, this study did not address the issue of long-term outcomes following concussive injury.

CONCLUSION

The current study demonstrates that using the existing concussion management guidelines in Australian football results in rapid return to play with no measurable impairment in playing performance and no increase in injury rates following return. These strategies are in agreement with current consensus guidelines for the management of concussion in sport[2,20] and suggest that this approach is safe and effective in the management of concussed Australian football players.

ACKNOLWEDGMENT

The authors thank Dr John Orchard for his assistance in the collection of injury data and Greg Planner (Champion Data Pty Ltd) for his assistance in collation of performance statistics. We also thank Drs Hugh Seward and Andrew Daff and members of the AFL Medical Officers Association for their support of the project.

REFERENCES

1. Army Individual Test Battery. Manual of Directions and Scoring. Washington, DC: War Department, Adjutant General's Office; 1944.
2. Aubry M, Cantu R, Dvorak J, et al. Summary and agreement statement of the 1st International Symposium on Concussion in Sport, Vienna 2001. *Clin J Sport Med*. 2002;12:6-11.
3. Barth JT, Macciocchi SN, Giordani B, Rimel R, Jane JA, Boll TJ. Neuropsychological sequelae of minor head injury. *Neurosurgery*. 1983;13:529-533.
4. Cantu RC. Second-impact syndrome. *Clin Sports Med*. 1998;17:37-44.
5. Cantu RC, Voy R. Second-impact syndrome: a risk in any contact sport. *Phys Sportsmed.* 1995;23:27-34.
6. Chen JK, Johnston KM, Frey S, Petrides M, Worsley K, Ptito A. Functional abnormalities in symptomatic concussed athletes: an fMRI study. *Neuroimage*. 2004;22:68-82.
7. Congress of Neurological Surgeons Committee on Head Injury Nomenclature. Glossary of head injury. *Clin Neurosurg.* 1966;12:386-394.
8. Efron B, Tibshirani RJ. *An Introduction to the Bootstrap. Monographs on Statistics and Applied Probability*. New York, New York: Chapman Hall/CRC Press; 1993.
9. Fleiss J. *Statistical Methods for Rates and Proportions*. New York, NY: John Wiley & Sons; 1981.
10. Gerberich SG, Priest JD, Boen JR, Straub CP, Maxwell RE. Concussion incidences and severity in secondary school varsity football players. *Am J Public Health*. 1983;73:1370-1375.
11. Gronwall D, Wrightson P. Cumulative effect of concussion. *Lancet*. 1975;2(7943):995-997.
12. Guskiewicz KM, Marshall SW, Bailes J, et al. Recurrent concussion and risk of depression in retired professional football players. *Med Sci Sports Exerc.* 2007;39:903-909.
13. Jantzen KJ, Anderson B, Steinberg FL, Kelso JA. A prospective functional MR imaging study of mild traumatic brain injury in college football players. *AJNR Am J Neuroradiol*. 2004;25:738-745.
14. Johnston KM, McCrory P, Mohtadi NG, Meeuwisse W. Evidence-based review of sport-related concussion: clinical science. *Clin J Sport Med.* 2001;11:150-159.
15. Johnston KM, Ptito A, Chankowsky J, Chen JK. New frontiers in diagnostic imaging in concussive head injury. *Clin J Sport Med*. 2001;11:166-175.
16. Jordan BD. Chronic traumatic brain injury associated with boxing. *Semin Neurol.* 2000;20:179-185.
17. Maddocks D, Saling M. Neuropsychological deficits following concussion. *Brain Inj*. 1996;10:99-103.
18. Makdissi M, Collie A, Maruff P, et al. Computerised cognitive assessment of concussed Australian rules footballers. *Br J Sports Med.* 2001;35:354-360.
19. Matser EJ, Kessels AG, Lezak MD, Jordan BD, Troost J. Neuropsychological impairment in amateur soccer players. *JAMA*. 1999;282:971-973.

20. McCrory P, Johnston K, Meeuwisse W, et al. Summary and agreement statement of the 2nd International Conference on Concussion in Sport, Prague 2004. *Br J Sports Med*. 2005;39:196-204.
21. McCrory PR, Ariens T, Berkovic SF. The nature and duration of acute concussive symptoms in Australian football. *Clin J Sport Med*. 2000;10:235-238.
22. Norton KI, Craig NP, Olds TS. The evolution of Australian football. *J Sci Med Sport*. 1999;2:389-404.
23. Orchard J, Seward H. Epidemiology of injuries in the Australian Football League, seasons 1997-2000. *Br J Sports Med*. 2002;36: 39-44.
24. Orchard J, Wood T, Seward H, Broad A. Comparison of injuries in elite senior and junior Australian football. *J Sci Med Sport*. 1998;1:83-88.
25. Pellman EJ, Powell JW, Viano DC, et al. Concussion in professional football: epidemiological features of game injuries and review of the literature—part 3. *Neurosurgery*. 2004;54:81-94; discussion 94-96.
26. Rutherford WH. Sequelae of concussion caused by minor head injuries. *Lancet*. 1977;1:1-4.
27. Weschler D. *Weschler Adult Intelligence Scale—Revised: Manual*. New York, NY: Psychological Corporation; 1981.