Sports-related concussion increases the risk of subsequent injury by about 50% in elite male football players

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Accepted 15 July 2014
Published Online First 31 July 2014

ABSTRACT

Background Little is known about the short-term and long-term sequelae of concussion, and about when athletes who have sustained such injuries can safely return to play.

Purpose To examine whether sports-related concussion increases the risk of subsequent injury in elite male football players.

Study design Prospective cohort study.

Methods Injuries were registered for 46 male elite football teams in 10 European countries in the 2001/2002–2011/2102 seasons. Two survival models were used to analyse whether concussion increased the subsequent risk of an injury in the first year.

Results During the follow-up period, 66 players sustained concussions and 1599 players sustained other injuries. Compared with the risk following other injuries, concussion was associated with a progressively increased risk of a subsequent injury in the first year (0 to <3 months, HR=1.56, 95% CI 1.09 to 2.23; 3 to <6 months, HR=2.78, 95% CI 1.58 to 4.89; 6–12 months, HR=4.07, 95% CI 2.14 to 7.76). In the second model, after adjustment for the number of injuries in the year preceding the concussion, this injury remained significantly associated with the risk of subsequent injury in the first year (HR=1.47, 95% CI 1.05 to 2.05).

Conclusions Concussion was a risk factor for sustaining subsequent injury within the following year. In-depth medical evaluation, which includes neurological and cognitive assessment, is warranted within the concussion management and return-to- play process.

INTRODUCTION

Sports are a major cause of concussion, often referred to as mild traumatic brain injury within general medicine.[1] Despite an estimated annual incidence of 1.6–3.8 million sports-related concussions in the USA alone, very little is known about the consequences of early return to play following such injuries.[2–4]

Traditionally, contact sports such as boxing, rugby union and American football have been associated with a high risk of concussion.[5] Recently, awareness of the potential consequences of head injuries has increased within other contact sports, such as football (used synonymously with 'soccer' in this paper unless specified), the most popular sport in the world with more than 265 million players.[6] Studies have investigated the incidence of concussion in football players of different ages, genders and participation levels. In general, the risk of concussion appears to be increasing over time,[7 8] and more than half of the players in some football leagues have a history of concussion, or symptoms corresponding to this type of injury.[9] Other researchers have reported that head injuries comprise 4–22% of all football injuries.[10]

In the short-term recovery period, concussion has been associated with at least short-term cognitive impairments affecting patients' attention, executive function and visuospatial skills.[11] This mild degree of cognitive impairment may make the player more vulnerable to injuries in the first weeks after trauma. Consistent with such risks after sports concussion, men in the general population who have reduced cognitive function are at increased risk of concussion and more severe head injuries than their cognitively normal peers.[12 13] The primary aim of this study was to examine the risk of subsequent injury after return to play in football players who had sustained concussions.

MATERIALS AND METHODS

This study is part of the on-going Union of European Football Associations (UEFA) Champions League injury study, which is a long-term prospective observational cohort study of the highest level of professional European football players. In short, 46 senior professional male football teams from the top divisions in 10 European countries were followed prospectively for 172 team-seasons (1–11 seasons) between July 2001 and June 2012. The teams' squad consisted of 28±8 players (range 15–57) with a mean age of 26±1 (range 22–30 years). The registration of exposure to, and occurrence of, injuries has been detailed previously.[14 15] The study design followed the consensus guidelines for definitions and data collection procedures for studies of football injuries outlined by the UEFA[14] and in the consensus document for football injury surveillance studies.[16] Based on type, injuries were diagnosed and registered in the injury database by each team, and classified as gradual onset (eg, tendinopathy, stress fracture and musculoskeletal pain) or sudden onset (eg, fractures, contusions, ligament sprains and muscle strains).

All injuries preventing players from participating fully in training or matches were recorded. Players were considered to be injured until medical staff had cleared them for full participation in training and availability for match selection. The local ethics committee of Linköping University approved the study protocol.

To cite: Nordström A, Nordström P, Ekstrand J. *Br J Sports Med* 2014;**48**:1447–1450.

Statistical methods

Characteristics are described using means and SDs, unless stated otherwise. Differences between groups were assessed using Student t test for independent samples or the χ^2 test. The risk of sustaining an injury subsequent to concussion was evaluated using two different statistical models. Cox proportional hazard models were used to compare the risk of sustaining a subsequent injury in participants with a concussion (n=66 cases), with that of sustaining a subsequent injury after a randomly selected non-concussion injury in the rest of the cohort (n=1599). Study end points for these models were the occurrence of a new injury or 365 days of follow-up, whichever came first. The models were adjusted for the influence of the number of injuries occurring in the previous year. Using a marginal model developed by Wei *et al*,[17] which is an extension of the Cox model, we compared the risks of injury in the 1-year periods before and after concussion in 66 players who had sustained concussions. This model included all injuries occurring during this time period in these players, with each participant considered to be at risk for all possible events. Separate baseline hazards were thus estimated for all events using stratification. In both models, we used the 'estat phtest' procedure (Stata software) to check for time-dependent effects. A p value <0.05 was considered significant. SPSS (V.20.0 for Macintosh; IBM Corporation, New York, USA) and Stata (V.12.1 for Macintosh; StataCorp, Texas, USA) were used for statistical analyses.

RESULTS

During follow-up periods of 1–11 seasons (range, 2001/2002–2011/2012), 1665 players on 46 European football teams sustained 8695 injuries. These injuries included 71 concussions in 66 players (table 1). No significant difference in age, weight or height was observed between players who did and did not sustain concussions. Compared with other injuries, concussions were associated with a shorter mean absence from training and matches (19.6 vs 9.9 days, p<0.001) and fewer missed matches (3.3 vs 1.7) and training sessions (11.9 vs 6.1) (p<0.001 for both comparisons).

In general, the 66 players who sustained concussions were more prone to injury than the rest of the cohort (mean, 11.5 vs 5.0 registered injuries; p<0.001; table 1). In the year preceding injury, more injuries occurred in players who subsequently sustained concussions than in the rest of the cohort in the year preceding a randomly selected injury (1.8 vs 0.9, p< 0.001; table 1). Table 2 lists the types and numbers of injuries occurring during the total follow-up time, that is, from the 2001/2002 season to the 2011/2012 season. Muscle injuries were the most common injuries both in players who sustained concussions and in the rest of the cohort.

To evaluate whether concussion was associated with an increased risk of subsequent injury, we compared the risk of one new injury in the year after concussion (n=66) with that of the risk after a randomly selected injury in the rest of the cohort (n=1599). As a formal test ('estat phtest' procedure) indicated that the risk of injury was time dependent (χ^2 test, p=0.008), we analysed these risks up to 3 months, 3 to <6 months and 6–12 months after injury. After adjusting for the number of injuries occurring in the year before injury (table 1), concussion was associated with a progressively increased risk of injury (0 to <3 months, HR=1.56; 3 to <6 months, HR=2.78; 6–12 months, HR=4.07; table 3). In separate analyses, concussion was found to increase the risks of sudden onset injuries and gradual onset injuries (table 3).

In the second model, the numbers of injuries before and after concussion were compared in the 66 players who sustained this injury. In the year before and after concussion, the 66 players with concussion sustained 127 and 153 injuries, respectively. The concussion was associated with a significantly increased risk of a subsequent injury in the first year (HR=1.47; 95% CI 1.05 to 2.05; table 4). This increased risk was not time dependent. Concussion increased the risk of sudden onset injury (HR=1.70; 95% CI 1.20 to 2.41), but not gradual onset injury (HR=1.00; 95% CI 0.60 to 1.66), in this analysis.

Table 1 Characteristics of players according to the occurrence of concussion during total follow-up time

	Concussion (n=66)	No concussion (n=1599)	p Value
Age (years)	25.3±4.2	26.2±4.4	0.10
Weight (kg)	78.7±6.8	78.2±7.2	0.57
Height (cm)	183±7	182±6	0.27
Mean number of injuries during total follow-up period	11.5±8.6	5.0±5.2	<0.001
Mean number of injuries in the year preceding concussion or randomly selected injury	1.8±1.6	0.9±1.4	<0.001

Table 2 Types of injury during the total follow-up period according to the occurrence of concussion

	Concussion (n=66)	No concussion (n=1599)
Concussion	71 (9%)	0 (0%)
Head/neck fracture	7 (1%)	48 (1%)
Shoulder sprain/dislocation	5 (1%)	95 (1%)
Shoulder/arm/elbow fracture	3 (0%)	13 (0%)
Forearm/wrist/hand fracture	8 (1%)	41 (1%)
Rib/chest wall injury	9 (1%)	71 (1%)
Lumbar/thoracic fracture	3 (0%)	13 (0%)
Lumbar/thoracic spine injury	29 (4%)	276 (3%)
Groin strain/osteitis pubis	68 (9%)	993 (13%)
Hip-joint injury	9 (1%)	45 (1%)
Hamstring muscle injury	93 (12%)	1269 (16%)
Hip/thigh contusion	21 (3%)	224 (3%)
Quadriceps muscle injury	42 (6%)	489 (6%)
Knee ACL injury	4 (1%)	66 (1%)
Knee/patellar tendon injury	14 (2%)	188 (2%)
Knee MCL injury	30 (4%)	354 (4%)
Knee osteochondral/meniscus injury	15 (2%)	201 (3%)
Other knee injury	24 (3%)	248 (3%)
Other knee sprain/dislocation	11 (1%)	123 (2%)
Knee/leg/ankle/foot contusion	80 (11%)	768 (10%)
Achilles tendon injury	13 (2%)	207 (3%)
Calf muscle injury	38 (5%)	439 (6%)
Leg/foot fracture/stress fracture	14 (2%)	131 (2%)
Other leg/ankle/foot injury	14 (2%)	218 (3%)
Ankle sprain/joint injury	86 (11%)	843 (11%)
Foot sprain/joint injury	3 (0%)	62 (1%)
Other injuries	42 (6%)	514 (7%)
Total	756 (100%)	7939 (100%)

Data are presented as n (%).
ACL, anterior cruciate ligament; MCL, medial collateral ligament.

Table 3 Risk of injury after concussion (n=66) or randomly selected injury (n=1599) in the year after the index trauma, divided into different time periods

	At least one injury (n=874)		At least one sudden onset injury (n=709)		At least one gradual onset injury (n=414)	
	HR	95% CI	HR	95% CI	HR	95% CI
0 to <3 months	1.56	1.09 to 2.23	1.76	1.12 to 2.76	2.44	1.36 to 4.37
3 to <6 months	2.78	1.58 to 4.89	3.00	1.52 to 5.92	4.36	1.57 to 12.10
6 to 12 months	4.07	2.14 to 7.76	3.69	1.72 to 7.95	7.94	2.39 to 26.44

Hazards were adjusted for the number of injuries in the year before the index injury.

DISCUSSION

The results of the study indicate that male football players who sustain concussions are generally more prone to injury, both prior and subsequent to incidence of concussion. The risk of subsequent injury during the total follow-up period was approximately 2.2 times greater in the concussed players. The risk of injury was also approximately two times greater in the year before concussion compared with randomly selected injuries in analyses that excluded the effect of concussion per se. These findings may be related to playing positions or styles of play that increase elite football players' risk of injury. After adjusting for this increased risk, the risk of subsequent injury in the first year after concussion remained higher than that after other injuries. Confirmation of these results in other types of athletes prone to head injuries and further evaluation of the mechanism underlying this increased risk would be valuable.

In addition to documenting an increased risk of injury after concussion, analysis of the total cohort demonstrated that the risk of all injury types increased gradually in the year after concussion, reaching about fourfold greater than that for other (non-concussive) injuries at 6–12 months. Although the analysis of hazards in the total cohort was adjusted for the number of injuries before the index trauma, it may not have accounted for other confounders influencing the risk of injury specifically in players who had sustained concussions. We thus conducted additional analyses of data from the years before and after concussion exclusively, which produced consistent results but yielded a lower risk value than in the total cohort, suggesting the presence of residual confounders in the initial analysis. Interestingly, concussion was associated with an increased risk of sudden onset, but not gradual onset injuries in this sub-cohort analysis, which is plausible from a mechanistic perspective. To the best of our knowledge, there are no previous studies that have investigated the relationship between concussion and the risk of subsequent injury in football players. However, we recently reported that concussion increased the risk of subsequent concussion by approximately twofold in a nationwide cohort of men, after adjustment for other confounders.[12]

These results are of great interest, given that current clinical guidelines suggest that a graduated return to play can be started once self-reported symptoms have resolved.[18 19] McCrea *et al*[20] followed 79 collegiate football players who had sustained concussions for up to 90 days after the trauma, finding that initial deficits affecting balance and cognitive function typically resolved within 1 week, with no significant difference from control participants after 90 days. In general, other studies of athletes have produced similar results with respect to the time required for full recovery,[20–22] which are supported by the mean absence from training and matches of 10 days in the present study. However, the cognitive tests used in these studies, such as the trial-making test,[23] may be insufficiently sensitive to detect subtle changes in neuropsychological domains in elite football players, such as reaction times, decision-making and perception. In support of this hypothesis, several retrospective imaging studies have shown deficits in axonal integrity[24 25] and grey matter lesions after concussion.[26]

Of special interest with respect to the sustained increased risk of additional injury after concussion, apoptosis and atrophy in the brain seem to be more prominent 6–12 months after a traumatic head injury than initially.[27 28] However, to the best of our knowledge, such brain abnormalities have not been associated with impairment in cognitive performance relative to that before the trauma. Nevertheless, our results may suggest that a more thorough medical evaluation is of importance after a concussion, focusing on assessment of neurological and cognitive functions. The results also suggest that following concussion, participants should be closely monitored for at least 1 year. Given that symptoms of concussion are often subtle, preseason tests of various aspects of cognitive function could be valuable in determining readiness to return to play and subsequent injury risk.

Several limitations of the present study should be considered. As the study included only elite male football players, the results may not be generalisable to the effects of concussion on other types of athlete or the general population. Diagnoses of concussion or concussion registered in the injury database could not be confirmed, and diagnostic criteria may have differed among

Table 4 Risk of subsequent injury in the year after concussion in 66 football players, after adjusting for the number of injuries in the preceding year

		Number of injuries			
	FU time	Pre concussion	Post concussion	HR	95% CI
All injuries	172±101	127	153	1.47	1.05 to 2.05
Sudden onset injuries	171±102	75	107	1.70	1.20 to 2.41
Gradual onset injuries	176±99	48	46	1.00	0.60 to 1.66

The mean follow-up time (FU time), number of injuries and HR together with 95% CI are presented.

teams and/or countries. Furthermore, football players with severe enough injuries who were forced to end their career or players who moved to a team that did not participate in the project could be lost to follow-up. To reduce this risk we restricted the follow-up time to 1 year for most analyses. Finally, the present database would not capture concussions sustained prior to 2001, or concussions sustained during traffic accidents or similar. However, participants lost during follow-up, any heterogeneity, poor sensitivity, poor specificity of diagnoses and missed diagnoses would likely attenuate the hazards associated with concussions towards zero.

In summary, we found a substantially increased risk of additional injury within the year after concussion in a cohort of elite football players. The results of this study are of interest within the context of current clinical guidelines,[18] which typically result in the commencement of a graduated return to play within 7–10 days of this trauma.

What are the new findings?

- There was an increased risk of a subsequent injury within the year following concussion in elite football players.
- Analysis of previous injury history revealed that those elite football players who subsequently sustained a concussion, had also suffered more injuries than their counterparts who did not suffer concussion (ie, concussion may be part of an 'injury prone' phenotype/behaviour).

How might it impact on clinical practice in the near future?

The increased risk of subsequent injury during the year following a concussion:

- Is of interest within the context of current clinical guidelines, which suggests that a graduated return to play should start after concussion-associated symptoms have subsided, which is usually within 7–10 days.
- May suggest that a more in-depth medical evaluation is necessary after a concussion, focusing on assessment of neurological and cognitive deficits. Given that symptoms may be subtle, comparing preseason and postconcussion tests of various aspects of cognitive function could be valuable to determine readiness to return to play and subsequent injury risk.

Contributors AN and JE conceived the idea for the study. PN and AN compiled and analysed the data, and made initial drafts of tables and results with input from JE. AN led the writing of the paper, with contributions from JE and PN.

Funding The study was supported by grants from UEFA and the Swedish National Center for Research in Sports.

Competing interests None.

Ethics approval The study design was approved by the UEFA Medical Committee and the UEFA Football Development Division.

Provenance and peer review Not commissioned; externally peer reviewed.

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Br J Sports Med 2014 48: 1447-1450 originally published online July 31, 2014
doi: 10.1136/bjsports-2013-093406