DO MINOR HEAD IMPACTS IN SOCCER CAUSE CONCUSSIVE INJURY? A PROSPECTIVE CASE-CONTROL STUDY

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OBJECTIVE: Our objective was to determine whether minor head trauma in elite soccer matches causes measurable impairment in brain function.

METHODS: Baseline neuropsychological testing was completed by professional soccer players in the Norwegian elite league, Tippeligaen, before the 2004 and 2005 seasons (n = 462). A player who experienced a head impact during a league match completed a follow-up test the next day (head impact group). Videotapes of all impacts were collected and reviewed. A group of players without head impacts was also tested after a league match to serve as controls (matched control group; n = 47).

RESULTS: A total of 228 impacts were identified, and 44 (19.3%) of these were followed up with a CogSport test (CogState, Ltd., Charlton South, Australia; the players who were tested tended to have more severe injuries, but there were only 6 cases with loss of consciousness). The head impact group had a greater change in reaction time from baseline to follow-up compared with the matched control group with regard to the 3 simplest tasks. The largest deficits were seen among the players reporting acute symptoms after the impact, but deficits were also demonstrated among asymptomatic players. Players who experienced 1 or more head impacts during the 2004 season showed a reduction in neuropsychological performance when tested before the 2005 season. However, none of these players was impaired when compared with the test manufacturer's normative data.

CONCLUSION: A reduced neuropsychological performance was found after minor head impacts in soccer, even in allegedly asymptomatic players. However, the long-term cognitive consequences are uncertain.

KEY WORDS: Brain injury, Closed head trauma, Neuropsychological tests

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Soccer is a vigorous sporting activity whereby 1 event with an injury potential occurs every sixth second of a competitive game, resulting in approximately 1 injury every 45 minutes (30). Between 6% and 15% of these injuries are head injuries (1, 13), which result mainly from aerial challenges for the ball with an unprotected head (2, 13).

Results from cross sectional studies performed in the 1990s suggested that repetitive subconcussive head impacts, including heading, could cause cognitive impairment among players (11, 22, 23, 37–39). However, a comprehensive review of the literature on this topic raised several concerns regarding the methods and study designs used, finding that there was no conclusive evidence that cognitive impairment occurred as a result of general soccer play or normal heading (31). This is consistent with biomechanical studies of linear and angular head acceleration during normal heading (4, 27). A study from the Norwegian soccer elite league revealed an incidence of events with a head injury potential of 22.0 per 1000 playing hours (2), compared with a reported concussion incidence of 0.3 per 1000 playing hours. Thus, it has been suggested that 4 of 5 concussions are not recognized by the players themselves (10). There are also concerns regarding the potential consequences of repetitive head impacts during play (18).

The main objective of our study was to determine whether minor head impacts caused measurable brain function impairment among

elite (top-echelon) soccer players. A secondary objective was to investigate whether there was any change in neuropsychological test performance from 1 year to the next for players who had experienced 1 or more minor head impacts during the course of the previous season.

PATIENTS AND METHODS

Study Design and Participants

A prospective case-control study was undertaken. Players contracted at the start of the 2004 and 2005 seasons in all 14 teams in the Norwegian elite soccer league, Tippeligaen, were invited to participate. Written informed consent was obtained at baseline for all participants. The study design was approved by the Regional Committee for Medical Research Ethics, Helse Sør, and the Data Inspectorate.

Baseline testing was performed for all players before the 2004 and 2005 seasons. Players who experienced a head impact during a regular league match were asked to participate in a follow-up test the next morning (head impact group). Their test results were compared with those of league players who experienced no head impact (matched control group). A 1-year follow-up evaluation was conducted whereby the cases, defined as players who had experienced 1 or more head impacts, were compared with the players in the cohort without any recorded head impacts.

Assessments

At baseline, the participants were asked to complete a questionnaire to document their history of head injuries, neurological disease, age at which they started organized soccer training, mean number of headings per match, learning disabilities, activity disorders, alcohol intake, and use of other drugs. In addition, a symptom assessment (Post Concussion Symptom Scale) (19) was completed at baseline and at all follow-up examinations.

Neuropsychological performance was assessed using a commercially available computer-based test battery (CogSport; CogState, Ltd., Charlton South, Australia). The test battery consists of 6 different tasks (psychomotor function, decision making, simple attention, divided attention, working memory, and learning and memory). The tasks and the sensitivity and reliability of the test are described elsewhere (7–9, 12, 21, 32, 33). Only the reaction time measurements were considered in this study.

At baseline, 2 consecutive CogSport tests were performed; the first was regarded as a practice run and discarded from further analyses (12, 33).

Head Impact Cases: Sampling and Evaluation

The participants were observed during all regular league matches, and all head impacts were recorded by local medical personnel present at the soccer arena (the team's medical personnel or other medical personnel with a background in soccer recruited by the administrators of the study). The study's definition of a head impact was: 1) the player appeared to have received an impact to the head (including the face and the neck), irrespective of the match situation; 2) the match was interrupted by the referee; and 3) the player had lain on the pitch for more than 15 seconds (2).

Players who met the head impact definition, irrespective of whether or not they were taken out of play, were evaluated clinically by the local medical personnel immediately after the match. Follow-up testing was performed the next day and supervised by a member of the team's medical staff.

Videotapes of all matches, provided by the Norwegian Broadcasting Corp., were reviewed the morning after the match. If 1 or more head impacts were identified, the team's medical personnel were contacted by telephone to check on the player's follow-up status and, if possible, arrange for follow-up testing. Video images of all head impacts were copied to a computer and saved for more detailed analysis. Details of head impacts that resulted in actual time loss injuries (14) were collected from the injury surveillance system in Tippeligaen administered by the Oslo Sports Trauma Research Center (1).

TABLE 1. Distribution of risk factors for head impacts that were followed up compared with those that were not[a]

Assessment	Head impact follow-up status		*P* value
	Followed up (n = 44, 19.3%)	Not followed up (n = 184, 80.7%)	
General			
Classification of the impact			
Definite	35 (79.5%)	144 (78.3%)	0.27
Doubtful	2 (4.5%)	21 (11.4%)	
Could not be assessed	7 (16.0%)	19 (10.3%)	
Global impression of severity			
Severe	13 (29.3%)	25 (13.6%)	0.04
Not severe	30 (68.2%)	154 (83.7%)	
Could not be assessed	1 (2.3%)	5 (2.7%)	
Returned to play			
No	17 (38.6%)	12 (6.5%)	<0.001
Yes	27 (61.4%)	172 (93.5%)	
Specific impact severity			
Horizontal speed and direction			
No relative speed	10 (23.3%)	61 (34.1%)	0.15
Low speed (toward)	21 (48.8%)	87 (47.8%)	
High speed (same direction)	9 (20.9%)	30 (16.5%)	
High speed (toward)	3 (7.0%)	3 (1.6%)	
Head movement contribution			
No head movement	26 (59.1%)	127 (69.1%)	0.64
One player	6 (13.6%)	21 (11.4%)	
Both	8 (18.2%)	24 (13.0%)	
Could not be assessed	4 (9.1%)	12 (6.5%)	
Location			
Frontal	3 (6.8%)	13 (7.1%)	0.45
Temporal/parietal	11 (25.0%)	31 (16.8%)	
Other	30 (68.2%)	140 (76.1%)	
Striking body part			
Head	15 (34.1%)	41 (22.3%)	0.36
Shoulder	3 (6.8%)	12 (6.5%)	
Elbow	5 (11.4%)	34 (18.5%)	
Other	21 (47.7%)	97 (52.7%)	

[a] Distributions were compared using the χ^2 test.

TABLE 2. Compliance with the test protocol for the prospective league study

	Preseason baseline		League players[b]	Season follow-up			
				Head impact group		Matched control group	
	No. of players[c]	Cog-Sport test		No. of players	Cog-Sport test	No. of players[a]	Cog-Sport test
2004 cohort	300	271 (90%)	326	105	17 (16%)	53	47 (89%)
2005 cohort							
Players from 2004	205	Impact: 37 (18%)[c] Control: 107 (52%)[c]	205	59	18 (31%)		
New 2005	181	133 (73%)	129	64	9 (14%)		
Total 2005	386	277 (72%)	334	123	27 (22%)		
Totals for both seasons	686	548 (80%)	660	228	44 (19%)	53	47 (89%)

[a] In the preseason period, there was considerable turnover within each team; thus, the exact number of players in the A-squad was difficult to assess. Consequently, some players who were tested at baseline did not play any matches in the next season.
[b] The term league players represents all players who were registered in the official match statistics for that particular season, including those who joined the teams after the baseline testing.
[c] Head impacts identified on video review of the league matches.

Matched Control Group

Players from the same cohort were recruited as controls (matched control group). After playing a regular league match in which they did not experience a head impact (as per the study definition) or other injuries, the players completed the same follow-up regime as the head impact group with postmatch symptom assessment and neuropsychological testing the next day.

One-Year Follow-up

The group of players who had experienced 1 or more head impacts during the 2004 season, irrespective of the follow-up status of these impacts, were defined as the season 1 head impact group and compared with players who had not experienced any head impacts during the 2004 season (season 1 control group).

Video Analysis

All head impact cases were analyzed independently on videotape by 2 of the authors (TMSN and ASM) according to the predefined general and specific impact severity assessments presented in Table 1. The results were then compared, and disagreements were reviewed in a consensus group meeting (TMSN, ASM, and TEA), at which a final decision was made. Two members of this group (ASM and TEA) were blinded to the injury outcome of the head impact cases. To assess whether there was any selection bias regarding follow-up status and impact severity, the severity of head impacts that were followed up with neuropsychological testing were compared with head impacts with no follow-up.

Effect Variables and Statistical Methods

The main effect variable was the global change in neuropsychological test performance from baseline to follow-up for the head impact groups (head impact and season 1 head impact), compared with the controls (matched control and season 1 control, respectively). If a significant difference was found, a post hoc test was performed to identify potential differences on each of the 6 subtasks. A within-person comparison was also performed to identify individual players with significant deteriorations from baseline to follow-up.

The test-retest differences in reaction times (delta values) for all 6 subtests were divided by their corresponding mean baseline reaction time to create a percentage change score. The global changes in neuropsychological performance between the groups were assessed using a (multivariate linear) model in which the percentage change for all 6 subtasks was entered at the same time (multivariate analysis of variance). Post hoc pair-wise t test comparisons with Bonferroni-corrected P values were performed to reveal significant differences between the examined groups for any of the 6 subtasks. All statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS, Inc., Chicago, IL).

RESULTS

Sample Population

Because of the considerable turnover of players within each team in the preseason (transfer) period, the exact number of players in the A-squad at the time of testing was difficult to assess (Table 2). A total of 326 players played in at least 1 regular match in Tippeligaen in 2004, and 334 players played in 2005 (league players in Table 2). The cohort comprised 455 individuals and 660 "player seasons" (1 player playing 1 season, 326 + 334) (Table 2). The players' mean age was 25.2 years (range, 18–34 years), and 317 (79.1%) of the players were Norwegian or Scandinavian. Preseason neuropsychological testing was completed for 68.3% of the players (452 of the 660 1-season league players).

A total of 205 of these players were active in both seasons, and 144 (70.2%) of them completed the preseason neuropsychological testing both years (2004 and 2005) and were thus available for 1-year follow-up evaluation.

Head Impact Identification and Video Evaluation

A total of 228 head impacts to 141 players who met the inclusion criteria were identified on video from the 352 matches

observed (i.e., 19.6 incidents per 1000 playing hours). Of these, 44 impacts (19.3%) were followed up with neuropsychological testing the next day (head impact group). A player removed from the match because of a head impact was more likely to be followed up than a player who returned to play (relative risk, 5.1; 95% confidence interval, 2.7–9.5). Of the incidents followed up, 29.5% (n = 13) were characterized as "severe" on the global impression of impact severity, compared with 13.6% (n = 24) of the missed incidents (relative risk, 2.2; 95% confidence interval, 1.2–3.9) (Table 1).

The 228 impacts resulted in 13 "time loss" injuries (5.7%) (14), which were reported through the injury surveillance system in Tippeligaen. Six of these were superficial cuts or facial fractures, whereas 7 (3.1%) were reported as concussions (0.6 per 1000 playing hours). Six of these concussions were included among the 44 cases in the head impact group, including 5 players with loss of consciousness, 2 of whom also had posttraumatic amnesia. In 2 of the cases, in which a time loss concussion was ultimately reported, the player had returned to play in the same game after the head impact.

Neuropsychological Testing

Global testing of the reaction time change from baseline to follow-up for all 6 neuropsychological test variables revealed a significant difference between the head impact group and the matched control group (Wilks' lambda = 0.82; $P = 0.008$). Post hoc tests revealed that the head impact group had a significant decrease in performance on the follow-up test for the 2 simplest tasks, psychomotor function and decision-making, compared with the matched control group (Fig. 1).

A total of 22 (50%) of the players in the head impact group reported 1 or more symptoms at the time of the incident. Headache was the most common symptom and was reported by 17 (38.6%) of the players in the head impact group, followed by dizziness (n = 12; 27.3%) and concentration problems (n = 8; 36.4%).

Both the symptomatic and the asymptomatic players were significantly different from the matched control group on the global test (Wilks' lambda: symptomatic = 0.76, $P = 0.008$; asymptomatic = 0.78, $P = 0.016$). Even though performance on the 3 simplest tasks was reduced among the asymptomatic and symptomatic players compared with the matched control group, significant differences were only demonstrated for the 2 simplest tasks, and for the symptomatic group only (Fig. 1).

Among the 27 cases from the head impact group who returned to play, 11 reported playing with 1 or more symptoms. The group who returned to play were significantly slower than the matched control group on the follow-up test (Wilks' lambda = 0.76; $P = 0.004$). The post hoc analyses of each subtest revealed the same trend as for the entire head impact group.

Neuropsychological Performance at 1-year Follow-up

From the 144 players who completed the preseason neuropsychological testing both years, we identified 107 players (74.3%) who did not experience any head impacts in the 2004 season (season 1 control group) and 37 players (25.7%) who had experienced at least 1 impact (season 1 head impact group). Most players (n = 31; 83.7%) experienced only 1 impact. The season 1 head impact group also had a higher proportion of players who played in a position that increased their risk of experiencing a head trauma, and they headed more frequently compared with the season 1 control group.

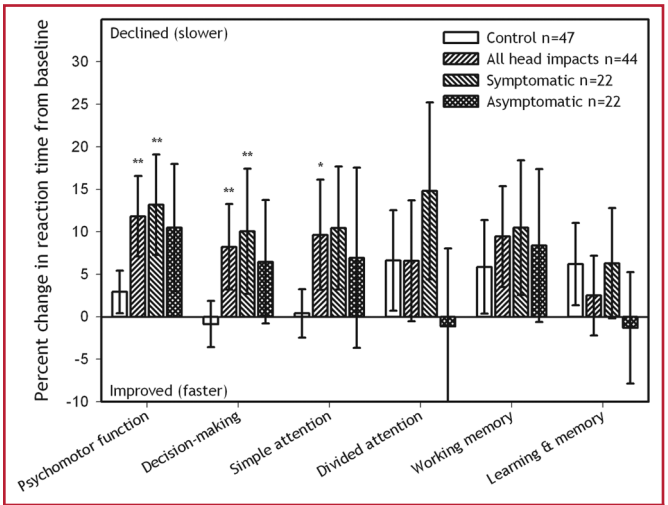

FIGURE 1. *Boxplot showing the change (%) in reaction time from baseline to follow-up for the head impact group and the matched control group. Data are also shown for symptomatic and asymptomatic players in the head impact group. *, P < 0.05 versus the matched control group; **, P < 0.01.*

At the 1-year follow-up evaluation (baseline 2005), the season 1 head impact group showed a larger increase in reaction times compared with the season 1 control group (Wilks' lambda = 0.91; $P = 0.043$). Figure 2 shows the change for the 6 subtests for the 2 groups. The post hoc tests revealed that the decision-making task was the only task that was significantly different between the 2 groups, whereas there was a trend in the same direction for the psychomotor function task.

DISCUSSION

This prospective study was designed to assess acute neuropsychological effects of minor head impacts in soccer. Players who had experienced a minor head impact showed significantly poorer performance as a group compared with controls, when tested the day after impact. Still, 50% of the followed-up cases claimed to be initially asymptomatic, 61% returned to play directly after the impact, and only 6 concussions were diagnosed by the teams themselves. However, the differences were limited to the 2 simplest subtasks in the test battery, and deficits were mainly found among the players reporting to be symptomatic directly after the head impact.

Limitations of the Study

Despite the presence of observers at every venue and contacting all teams the day after the match if a head impact was iden-

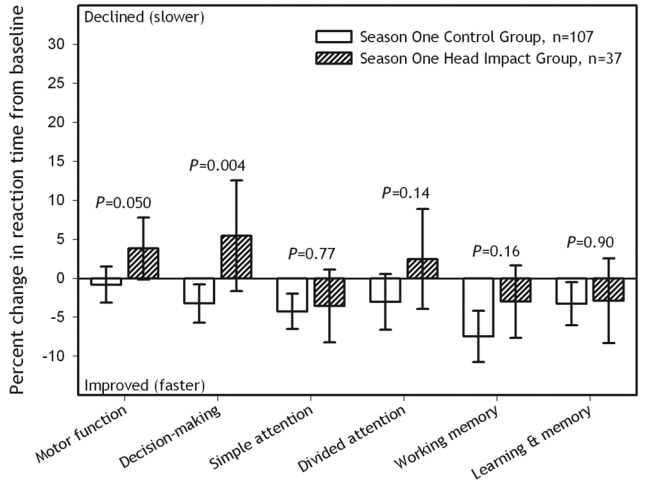

FIGURE 2. *Boxplot showing the change (%) in reaction time from baseline 2004 to baseline 2005 for players with (season 1 head impact) and without (season 1 control) a registered head impact during the 2004 season (n = 144).*

tified on the video review of the match, only 19.3% of the head impacts were followed up with neuropsychological testing. In general, the video analyses revealed that the impacts that appeared to be more severe and after which the player did not return to play were more likely to be followed up. The main reason for the low compliance was that players were reluctant to be tested after these impacts, which they regarded as trivial. As reflected by the lack of symptoms and the low concussion rate, the vast majority of the followed-up impacts were benign and thus representative of the minor head impacts that occur in competitive football. Nevertheless, the low compliance with follow-up testing represents the main limitation of this study and must be considered when interpreting the findings.

Interpretation of the Neuropsychological Performance

This study is the first to prospectively assess neuropsychological changes after head impacts during regular soccer matches, irrespective of whether the impacts were diagnosed as concussions or not. However, several studies have assessed initially concussed athletes whose symptoms had resolved after a few minutes or by the time of testing (6, 20, 28). Consistent with the findings in our study, there seems to be an agreement that the largest deficits in neuropsychological performance are found for the players who are symptomatic at the time of testing (15). Other studies have revealed electrophysiological changes (40) as well as neuropsychological deficits (10) among concussed athletes whose symptoms have allegedly resolved. Our study is the first to demonstrate neuropsychological deficits after minor head impacts for which the player did not report any acute concussive symptoms.

The participants in the head impact group and the matched control group did not differ in the mean number of headers per player per match, and thus, the main difference between the 2 groups was the head impacts. This is in contrast to previous, retrospective design studies, for which it was difficult to separate the effects of heading versus subconcussive head trauma (26).

The study protocol included assessment of S100B as a serum marker for brain cell injury, and, consistent with the neuropsychological findings, the blood sample analyses did not reveal any evidence of significant brain cell injury after minor head impacts (35). Nevertheless, some deficits in cognitive function were observed in the head impact group compared with players who had no head impacts.

Long-term Effects

Neuropsychological impairments from concussions have been shown to resolve within 3 to 7 days after the incident (5, 24). In contrast, this study found that the players who experienced a head impact during the 2004 season exhibited a significant, albeit small, reduction in neuropsychological performance from 1 year to the next. These players headed more frequently, and more of them played in a position that increased their risk of injury, compared with the uninjured players. However, the 2004 baseline assessment of the same cohort revealed no effects of heading frequency and concussion history on neuropsychological performance (34). It has been suggested that pre- and posttest comparisons for each individual are more sensitive than control group comparisons for detecting neuropsychological effects of head injury (36), and this could partly explain this discrepancy. The season 1 head impact group results examined in context show that all 37 follow-up tests were within the normal range defined by the test manufacturer, and only 4 players (10.8%) showed a decreased performance on 2 or more subtests. Consequently, the clinical significance of the statistical deficits demonstrated for the season 1 head impact group compared with the season 1 controls is not known.

Clinical Implications

These findings support the suggestion that concussive symptoms are often not recognized by the players (25) and that, if recognized, symptoms are underreported (17). Even though the players in the head impact group who returned to play were allegedly asymptomatic and considered fit to play the remainder of the match, many reported at the time of testing that they had indeed experienced symptoms of concussion directly after the impact or experienced a delayed onset of symptoms.

There is currently no consensus in the literature whether returning to play in the same match when asymptomatic after a concussion involves a risk of prolonged symptoms or further damage to the brain (3, 16, 29). However, these athletes do exhibit reduced reaction time, perceptual skills, etc., which increases susceptibility to other injuries.

Of the 228 incidents verified, only 7 concussions were reported. Five players experienced loss of consciousness, and 2 of them also had posttraumatic amnesia. Thus, it seems obvious that the teams' medical personnel still refer to the pre-Vienna concussion criteria (3), which stated that loss of consciousness or amnesia was mandatory. Importantly, our

findings emphasize the need for an increased awareness of concussion signs and symptoms, not only among the teams' medical personnel, but also among the players themselves.

CONCLUSION

A reduced neuropsychological performance was evident after minor head impacts in soccer, even in allegedly asymptomatic players. However, the followed-up impacts represented the more severe spectrum of the head impacts in soccer. Nonetheless, only 6 of these impacts were reported as concussions. In addition, preseason test performance was somewhat reduced from 1 year to the next in players who had experienced 1 or more head impacts during the season, although not when compared with the test manufacturer's normal range. Consequently, the clinical significance of this finding is uncertain.

DISCLOSURES

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COMMENTS

This study was designed to investigate recovery from head injury in a sample of Norwegian elite soccer players. The study presents very interesting data that contribute to our general understanding of mild traumatic brain injury in athletes. This is a very important area and has been the subject of a great deal of scientific activity over the past decade.

There are several unique aspects of this study that are of particular interest. First of all, the authors' assessment of videotape of the injuries represents an important addition to the literature. They also used both baseline neuropsychological testing as well as a noninjured control group, both of which are desirable components of a study of this nature. The overall findings of the study are consistent with prior research that indicates that neuropsychological testing provides useful information in the management of concussion.

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With this study, Straume-Næsheim et al. have contributed to the evolving literature on mild traumatic brain injury. The authors investigated the effects of minor head trauma in elite soccer players. They prospectively studied members of 14 professional teams from 2004 to 2005. Video of games was reviewed to identify occurrences of head impact, defined as an apparent impact to the head that resulted in interruption of play by the referee and the recumbency of the player for at least 15 seconds. During the 2004 season, players meeting this definition of head impact and controls who did not experience head impact were offered follow-up neuropsychological testing on the day after the game. In addition, the authors conducted preseason testing in 2004 and 2005, comparing the results of players who did and did not have head impacts during the 2004 season.

By focusing on witnessed impacts rather than on diagnosed concussions, the authors effectively used a broader definition of traumatic head injury than has traditionally been invoked. Their findings of both acute and 1-year deficits among players with head impact, compared with those without head impact, are thus impressive and warrant further consideration. In particular, the observation that even players with head impact who did not report acute symptoms had deficits is compelling. The fact that differences were detected with a relatively small sample size reinforces the significance of the findings. However, it is important to note that all players with head impact who were followed for a year had results on follow-up testing that fell within the normal range, and declines in performance tended to be limited to 1 subtest. The long-term implications of these findings for neurological function are currently unknown and will require more prolonged follow-up studies.

Many of the largest and most comprehensive studies of mild traumatic brain injury have investigated the effects of head injury in American football players. Compared with American football players, who are required to wear helmets, the soccer players studied by Straume-Næsheim et al. experienced unprotected head impacts. It is possible that the lack of protective equipment magnified the effects of impact, particularly with respect to 1-year outcomes. Considering the popularity of soccer worldwide at every level, Straume-Næsheim et al. have taken on a subject of immense importance that deserves ongoing attention.

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Much of the value of the present study comes from the questions it raises rather than from those it answers. Moreover, the authors are forthright about not having answers to some of the questions and resist speculation regarding the answers, at times adopting an attitude of puzzlement. Indeed, the finding of cognitive impairment, although quite mild and of unknown significance, after nonconcussive head injuries is quite provocative and offers some caution with regard to prematurely closing the argument on the duration of impairment after concussion. Other findings in this study are interesting as well, particularly the comparison of filmed injuries rated by independent experts and actual clinical care and on-field behavior. This study, as the authors admit, is limited by a small sample size, but it definitely raises the need for replication studies to determine whether this is an isolated accidental finding or a consistently reproducible one.

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