[Primary Care]

Twelve Years of National Football League Concussion Data

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Background: Concussion in the National Football League (NFL) remains an important issue. An initial description of the injury epidemiology involved 6 years from 1996 to 2001.

Hypothesis: The increased attention to concussions may have resulted in team physicians being more conservative in treating players in recent years.

Study Design: Two consecutive 6-year periods (1996-2001 and 2002-2007) were compared to determine changes in the circumstances associated with the injury, the patterns of signs and symptoms, and the players' time loss from participation in the NFL.

Methods: During 2002-2007, concussions were recorded by NFL team physicians and athletic trainers using the same standardized reporting form used from 1996 to 2001. Player position, type of play, concussion signs and symptoms, loss of consciousness, and medical action taken were recorded.

Results: There were 0.38 documented concussions per NFL game in 2002-2007—7.6% lower than the 0.42 in the earlier period (1996-2001). The injury rate was lower in quarterbacks and wide receivers but significantly higher in tight ends during the second 6 years. The most frequent symptoms were headaches and dizziness; the most common signs were problems with information processing and immediate recall. During 2002-2007, a significantly lower fraction of concussed players returned to the same game, and more were removed from play. Most concussed players (83.5%) returned to play in < 7 days; the percentage decreased to 57.4% with loss of consciousness. The number of players returning in < 7 days was 8% lower during 2002-2007 and 25% lower for those with loss of consciousness.

Conclusion: The most recent 6 years of NFL concussion data show a remarkable similarity to the earlier period. However, there was a significant decrease in the percentage of players returning to the same game, and players were held out of play longer.

Clinical Relevance: There was a more conservative management of concussion in NFL players from 2002 to 2007 even though the clinical signs and symptoms remained similar to the earlier 6-year period.

Keywords: concussion; traumatic brain injury; injury epidemiology; sport injury prevention

Pellman et al³⁻⁷ reported on the epidemiology of concussion in the National Football League (NFL) using a 6-year period from 1996 to 2001. They described the incidence by player position, type of play, signs and symptoms,³ repeat injuries,⁶ players out 7+ days,⁵ and players who return to the same game.^{2,4} The collection of game-related concussion data has continued in the NFL through the efforts of team physicians and athletic trainers. In this study, a consecutive data set of 6 years is reported for 2002 to 2007 and compared to the earlier published data (1996-2001).

Since 1980, the NFL has collected epidemiological data on injuries to its players. In 1995, the league started a special data collection that added clinical information on concussions to the existing information regarding the circumstances at the time of injury.³ NFL team physicians and athletic trainers documented concussions using a standardized reporting form. A broad yet specific definition of concussion was adopted at the beginning of the NFL research that was different from that proposed by the Third International Symposium on Concussion in Sports (Zurich, Switzerland) but was used for consistency.

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Mild traumatic brain injury (MTBI), or concussion, was defined as a traumatically induced alteration in neural function. The NFL team physicians recorded data on the clinical signs and symptoms at the time of the concussion and during follow-up examinations.

Throughout the 12-year study period, a reportable concussion was defined as a traumatically induced alteration in brain function, which is manifested by:

- alteration of awareness or consciousness, including but not limited to being dinged, dazed, stunned, woozy, foggy, amnesic, or, less commonly, rendered unconsciousness; and
- signs and symptoms commonly associated with postconcussion syndrome, including persistent headaches, vertigo, light-headedness, loss of balance, unsteadiness, syncope, near syncope, cognitive dysfunction, memory disturbance, hearing loss, tinnitus, blurred vision, diplopia, visual loss, personality change, drowsiness, lethargy, fatigue, and inability to perform usual daily activities.³

The present study is the result of the multiyear effort to increase knowledge on concussions. The purpose was to identify the circumstances present at the time of a concussion and to examine the pattern of signs and symptoms through initial and follow-up evaluations until a player returned to participation in practice or play. This study compares the first 6 years of the concussion data from 1996 to 2001^{1,3-7} with the most recent 6-year data from 2002 to 2007.

MATERIALS AND METHODS

The NFL Injury Surveillance System provides a mechanism for the athletic trainers and team physicians to record data regarding the characteristics surrounding a player's injury. It requires that the medical staff of each team record data for concussions that occur regardless of the amount of time lost to participation from the injury. The data include player time loss, player position, player activity, and team activity at the time of injury. In addition, a simple set of forms was developed for the team physicians to complete on observed and reported signs and symptoms of concussion when the player is injured and during follow-up visits. Details on the reporting methods can be found in Pellman et al.³

This report compares the 1996-2001 and 2001-2007 concussions reported by team physicians and athletic trainers for preseason, regular season, and postseason games. Each reported case includes (1) clinical information recorded by the team physician and (2) athletic training room data on the circumstances at the time of injury.

Signs and Symptoms

The signs and symptoms of concussion were grouped into 6 categories: general symptoms, cranial nerve symptoms, memory problems, cognitive problems, somatic complaints, and unconsciousness. Players reported many of the symptoms

spontaneously, but the complete symptom complex was elicited by physician questions, including mental status findings at rest and on exertion (ie, retrograde amnesia, anterograde amnesia, problems with information processing, attention, and immediate recall).

Data Documentation

The physician's initial and follow-up reporting concussion forms were designed to provide a detailed description of the signs and symptoms of concussion during initial and follow-up evaluations. The operational definition of concussion and reporting forms remained constant over the 12 years of data collection. Specific efforts to improve the consistency of the data have been described.³⁻⁵ The initial clinical evaluation form was designed to be completed at the time of the injury, and the follow-up evaluation form was to be completed each time the physician evaluated a player until he returned to full participation. The data forms were sent to the NFL epidemiologist and entered into the database.

The concussion reporting forms were logged in and scanned into a database file using a commercial software program (Teleforms, Cardiff, California). During the data logging, individual forms were manually reviewed. Each form was then scanned into a temporary database and verified before being entered into the final database. In a few cases, fields that were incomplete or inconsistent triggered a follow-up contact with the team athletic trainer or physician to verify the data. As the concussion data were merged with the injury surveillance data, the data were again reviewed and verified. The final database includes information from the initial and follow-up evaluation forms submitted by team physicians, as well as game-related circumstances at the time of injury.

Data Analysis and Statistics

Data for this analysis includes concussions that occurred during games in 2002-2007, which were then compared with the original database of concussions in 1996-2001. The data reflect cases that occurred during preseason, regular, and playoff games. The elimination of injuries during practice sessions allowed the analysis of game injuries and injury rates based on player positions per game and number of plays.

Each concussion was analyzed as an independent event. Summary measures are reported with 95% confidence intervals and significant differences with $P < 0.05$. Injury rates per 100 game positions (gp) were calculated to provide perspective on the risk of injury among the position categories. The denominator for these rates reflects the number of standard position players multiplied by the number of team games during the study periods. For example, there is 1 quarterback position for each team in each game: gp exposure = 1×3826 . For the offensive line, there are 5 positions per team (1 center, 2 guards, 2 tackles): gp exposure = 5×3826 . The injury rates are standardized over 100 team games. For consideration of the type of play at the time of injury, the data were partitioned to

Table 1. Descriptive data for the two 6-year study periods of concussion in the National Football League.^a

	1996-2001	2002-2007	Difference, %
All play			
No. of team seasons	183	192	4.9
No. of MTBI	887	854	-3.7
MTBI average / year	147.8	142.3	-3.7
MTBI average / team / year	4.8	4.4	-8.3
No. of players injured	649	641	-1.2
No. of players with repeat injury	108	111	2.8
Team games			
No. of game MTBI	787	758	-3.7
No. of team games	3826	3990	4.3
Injury rate / team game	0.21	0.19	-7.6
Cases with loss of consciousness	59	57	-3.4
Days lost			
Mean	1.92	4.73	146
Standard deviation	5.1	15.6	206
Median	0.0	1.0	
Range	0-98	0-237	

^aMTBI, mild traumatic brain injury.

include only regular season game-related cases. This allowed the opportunity to examine the injury pattern with an injury rate per 1000 plays based on data from the NFL record books regarding the number of plays in the regular season.

RESULTS

During the 2002-2007 NFL seasons, there were 758 fully documented concussions reported in 3990 team games, or 195 games (Table 1). In the previous 6 NFL seasons (1996-2001), there were 787 fully documented concussions reported in 3826 team games, or 1913 games. There were 142.3 concussions reported by team physicians and athletic trainers per year in 2002-2007, compared to 147.8 per year in the 1996-2001 seasons. The injury rate was 0.19 per team game in 2002-2007, compared to 0.21 per team game in 1996-2001. The mean days lost with concussion increased from 1.92 days to 4.73 days, with a much lower difference in days lost based on the medians of 1.0 in 2002-2007 and 0.0 in 1996-2001. There

were 787 fully documented game-related concussions reported in 3826 team games during the 1996-2001 seasons. This represents 0.21 reported injuries per team game, or 1 MTBI every 5 team games. For the 2002-2007 seasons, there were 758 concussions in 3990 team games for an injury rate of 0.19 injuries per team game or 1 every 5 team games.

Table 2 examines the patterns of injury based on the circumstances at the time of injury and position played. Tight ends had a 54% statistically significant increase in injury rate from the 1996-2001 to the 2002-2007 seasons (0.94 per 100 gp vs 1.45 per 100 gp, $P < 0.05$). The kick return unit had an increase in the injury rate (0.086 per 100 gp vs 0.14 per 100 gp, $P < 0.05$). At the same time, the defensive line showed a 41% decrease in injury rates (0.44 per 100 gp vs 0.26 per 100 gp, $P < 0.05$), and the kick unit experienced a decrease of 30% (0.34 per 100 gp vs 0.26 per 100 gp, $P < 0.05$). During 2002-2007, the injury rate for quarterbacks dropped to 1.20 per 100 gp from the earlier level of 1.62 per 100 gp, although the trend was not statistically significant. There was no change in the

Table 2. Incidence of mild traumatic brain injury according to player position in the National Football League.^a

	n		%		Game Positions		Injury Rates / 100 Team Games				Incidence Density Ratio 1996/2002	
	1996-2001	2002-2007	1996-2001	2002-2007	1996-2001	2002-2007	1996-2001		2002-2007			95% CI
								95% CI		95% CI		
Offensive												
Quarterback	62	48	7.9	6.3	3826	3990	1.62	1.22, 2.02	1.20	0.84, 1.52	1.35	0.94, 2.01
Wide receiver	94	73	11.9	9.6	7652	7980	1.23	0.98, 1.48	0.91	0.69, 1.11	1.34	1.00, 1.84
Tight end	36	58	4.6	7.7	3826	3990	0.94	0.63, 1.25	1.45	1.10, 1.86	0.65	0.42, 0.96
Running back	69	69	8.8	9.1	7652	7980	0.90	0.69, 1.11	0.86	0.65, 1.06	1.04	0.75, 1.48
Offensive line	56	56	7.1	7.4	19 130	19 950	0.29	0.21, .057	0.28	0.20, 0.35	1.04	0.72, 1.51
Defensive												
Secondary	143	148	18.2	19.5	15 304	15 960	0.93	0.78, 1.08	0.93	0.78, 1.08	1.01	0.79, 1.26
Linebacker	52	73	6.6	9.6	11 478	11 970	0.45	0.33, 0.57	0.61	0.47, 0.75	0.74	0.52, 1.06
Defensive line	67	42	8.5	5.5	15 304	15 960	0.44	0.34, 0.54	0.26	0.18, 0.34	1.66	1.13, 2.44
Special teams												
Kick unit	131	105	16.6	13.9	38 260	39 900	0.34	0.28, 0.40	0.26	0.21, 0.31	1.30	1.00, 1.68
Return unit	33	56	4.2	7.4	38 260	39 900	0.86	0.06, 0.12	0.14	0.10, 0.18	0.61	0.40, 0.94
Ball carrier	22	18	2.8	2.4	3826	3990	0.58	0.34, 0.82	0.45	0.24, 0.66	1.27	0.68, 2.37
Punter	7	4	0.9	0.5	3826	3990	0.18	0.05, 0.31	0.10	0.00, 0.20	1.83	0.54, 6.12
Kicker, FGA	1	4	0.1	0.5	3826	3990	0.03	-0.02, 0.08	0.10	0.00, 0.20	0.26	0.03, 1.99
Kicker, PAT	1	1	0.1	0.1	3826	3990	0.03	-0.02, 0.09	0.03	0.00, 0.07	1.04	0.06, 16.97
Kicker, KO	0	3	0.0	0.4	3826	3990	0.00	—			—	—
Holder	1	0	0.1	0.0	3826	3990	0.03	-0.02, 0.09	—	—	—	—
Unknown	12	0	1.5	0.0								
Total	787	758	100	100	3826	3990	20.6	19.13, 22.00	19.0	17.60, 20.20	1.08	0.98, 1.20

^aCI, confidence interval; FGA, field goal attempt; PAT, point after touchdown; KO, kickoff. Dashes (—) indicate no estimate available.

Table 3. Type of play for concussed players in National Football League games.

	n		%		P
	1996-2001	2002-2007	1996-2001	2002-2007	
Passing	282	270	35.8	35.6	NS
Rushing	246	183	31.3	24.1	< 0.01
Kickoff	125	156	15.9	20.6	< 0.05
Punt	75	52	9.5	6.9	NS
Change	9	19	1.1	2.5	NS
Field goal attempt	2	0	0.3	0.0	
Point after touchdown	1	5	0.1	0.7	NS
Unknown	47	73	6.0	9.6	< 0.05
Total	787	758	100.0	100.0	

injury rates for all other positions. The overall injury rate per 100 team games decreased 7.8% (20.6 per 100 team games vs 19.0 per 100 team games), although the change was not statistically significant.

During 2002-2007, 24.1% of reported concussions occurred in rushing plays, which was significantly lower than the 31.3% ($P < 0.01$) in the earlier 6 years (Table 3). In contrast, concussions in kickoffs significantly increased to 20.6% from 15.9% ($P < 0.05$). The rushing plays show a statistically significant decrease of 24% in the 2002-2007 seasons (1.71 per 1000 plays vs 2.24 per 1000 plays, $P < 0.05$), whereas the injury rates for the other types of play were similar (Table 4). The injury rate was highest on kickoffs, at 8.7 per 1000 plays in 2002-2007, compared to 7.7 per 1000 plays in 1996-2001 (NS), followed by punts, at 2.89 per 1000 plays in 2002-2007, compared to 3.86 per 1000 plays in 1996-2001 (NS). The difference for the passing plays was also not statistically significant.

The percentage during tackling significantly decreased from 31.9% in 1996-2001 to 26.0% in 2002-2007 ($P < 0.05$) (Table 5). Concussions by being blocked significantly increased in 2002-2007 to 19.4% from 13.2% in 1996-2001 ($P < 0.01$). Of the 33 signs and symptoms, 31 demonstrated no difference in incidence between the two 6-year periods (Table 6). The most common reported signs and symptoms remain headaches (56.1% vs 55.0%, NS), dizziness (40.6% vs 41.8%, NS), problems with information processing (20.2% vs 17.5%, NS), and problems with immediate recall (18.3% vs 25.5%, $P < 0.06$). The total number of reported signs and symptoms was similar for the two 6-year periods. Photophobia significantly increased to 6.9% of players, compared with 4.1% ($P < 0.05$) in the earlier period. Cognitive problems decreased to 20.2%, compared with 27.6% ($P < 0.05$).

The number of players immediately returning to the game significantly decreased to 8.4% in 2002-2007, compared with 16.5% in 1996-2001 ($P < 0.01$) (Table 7). This includes players who were evaluated on the field and returned or who came out of the game for a few plays and then returned to play. The percentage of players removed from the game significantly increased to 50.7% in 2002-2007, compared to 44.8% in 1996-2001 ($P < 0.05$).

During 2002-2007, 16.5% of players were out 7+ days with concussion, which was more than twice as many as in the earlier 6-year period (Figure 1). Even more players were held out 14+ days in the most recent period (5.9% vs 1.8%). The fraction of players out 7+ and 14+ days increased when there was loss of consciousness (LOC). In the 2002-2007 period, 42.6% of players with LOC were held out 7+ days.

DISCUSSION

There is a remarkable similarity in the data collected during the two recent 6-year periods. There were no cases of subdural hematoma, epidural hematoma, diffuse cerebral edema, or any other neurosurgical catastrophic lesion during either period. There was 1 case of a unilateral frontal cerebral contusion hemorrhage during the second 6-year period, and no such cases during the first 6-year period. The player who sustained this small contusion hemorrhage was treated conservatively, and the hemorrhage resolved fully without neurosurgical intervention. That player ultimately made a full clinical recovery and returned to play. Although there was a trend toward fewer MTBIs during the second 6-year period, this was not statistically significant. The percentage of players who experienced LOC associated with concussion remained below

10% during both periods. With few exceptions (discussed later), the signs and symptoms of MTBI were present in similar percentages during both 6-year periods. The incidence of repeat MTBIs was similar during both 6-year periods. A few areas of difference in the data between the two 6-year periods require further comment.

There are a number of possible explanations for the decrease in percentages of players immediately returning to play and returning to play on the day of the injury, as well as the increased days out after MTBI during the recent 6-year period, compared to the first 6-year period. These include the possibility of increased concussion severity, increased player willingness to report symptoms to medical staff, adoption of a more cautious conservative approach to concussion management by team medical personnel, and a possible effect of changes in neuropsychological (NP) testing.

The clinical data reported are inconclusive regarding the possibility that the severity of MTBIs increased during the second 6-year period. Almost all of the symptoms and signs of MTBI (including all of the most frequently associated symptoms and signs) occurred in a similar frequency pattern during the two 6-year periods. The total number of symptoms and signs also did not change. However, it is possible that the severity of symptoms (eg, headache, dizziness) has increased although the frequency has not. The increased frequency of photophobia noted during the second 6-year period suggests that more of the headaches being reported are migraines and thus more severe than the headaches reported during the first 6-year period. The 53 cases of headache and photophobia on initial evaluation in the 2002-2007 cohort, compared to 29 cases in the 1996-2001 cohort (83% increase) is consistent with the hypothesis that more of the headaches were migraines during the latter 6-year period.

If symptoms and/or signs were more severe during the second 6-year period, then one might expect that at least some of the symptoms and/or signs should be more long-lasting. There was an increased incidence of photophobia in the second 6-year period compared to the first that persisted on the first and second evaluations but disappeared on the third and subsequent follow-up evaluations. Given that the presence of any symptoms generally precludes RTP, this excess of players with persistent symptomatology during the first few days following concussion may be one of the factors causing the prolongation of the mean and median times to RTP during the second 6-year period.

In an earlier study, we found that during the first 6-year period, certain signs and symptoms at initial evaluation predicted a more prolonged recovery.^{1,3-7} Such signs and symptoms can thus be seen as potential indicators of more severe injury, at least from a clinical point of view. One of these symptoms was photophobia; as such, the increased incidence of photophobia in the second 6-year period could be an indicator of a prolonged RTP. However, cognitive and memory impairments were also associated with more prolonged recovery during the first 6-year period, but their

Table 4. Injuries according to type of play for concussed players during regular-season National Football League games.^a

	n		%		Plays, n		Risk / 1000 Plays		Incidence Density Ratio 1996/2002	
	1996-2001	2002-2007	1996-2001	2002-2007	1996-2001	2002-2007	1996-2001	2002-2007		95% CI
Kickoff	109	131	18.2	20.8	14 157	15 064	7.70	8.70	0.89	0.69, 1.14
Punt	57	43	9.5	6.8	14 767	14 874	3.86	2.89	1.34	0.90, 2.00
Rushing	183	147	30.5	23.3	81 692	85 847	2.24	1.71	1.31	1.05, 1.62
Passing	206	231	34.3	36.6	96 447	100 037	2.14	2.31	0.92	0.77, 1.12
Other	45	79	7.5	12.5						
Subtotal	600	631	100.0	100.0						
Preseason or postseason	187	127	31.2	20.1						
Total	787	758								

^aCI, confidence interval.

Table 5. Injuries by activity for concussed players in National Football League games.

	n			%		P
	1996-2001	2002-2007	Total	1996-2001	2002-2007	
Tackling	251	197	448	31.9	26.0	< 0.05
Tackled	225	200	425	28.6	26.4	NS
Blocking	128	119	247	16.3	15.7	NS
Blocked	104	147	251	13.2	19.4	< 0.01
Other	79	95	174	10.0	12.5	NS
Total	787	758	1545	100.0	100.0	

incidence decreased during the second 6-year period, arguing against the proposal that the injuries were more severe in those later years.

The total number of signs and symptoms present at initial evaluation was an indicator of prolonged recovery during the first 6 years.^{1,3-7} The two 6-year cohorts were found to be statistically similar in terms of average number of symptoms per MTBI case: 2.75 ± 2.40 (range, 0-12) in 2002-2007, compared to 2.75 ± 2.21 (range, 0-15; $P = 1.0$), arguing against the hypothesis that the injuries were more severe during the second 6-year period. Another way to evaluate the effect of the extra 20 cases of photophobia during the second 6-year period is to consider the total number of signs and symptoms occurring with cases of photophobia.

There was no statistical difference between the number of symptoms occurring with and without photophobia between the two 6-year periods (Table 8). During both 6-year periods, the average total number of symptoms doubled when a player had photophobia (5.3 to 5.6 with photophobia, compared to 2.5 to 2.6 without). Given that earlier studies demonstrated that RTP intervals of greater than 7 days were associated with a greater number of total symptoms on initial evaluation, the extra 20 cases of photophobia represent a higher number of symptoms, and more likely a prolonged RTP. Overall, the data are inconclusive regarding the question of whether the injuries were more severe during the second 6-year period.

Another possible explanation for the decrease in percentage of players returning to play on the day of the injury and the increased time interval before being cleared to RTP is that players were more forthright and open in reporting their symptoms to team medical personnel during the second 6-year period. Such a change in player behavior could have occurred as a result of player education about MTBI conducted by the league and the NFL Players Association and because of increased public and media awareness of the significance of concussion. Such an increased reporting of symptoms would

have the effect of fewer players meeting the requirement of being asymptomatic before being considered for RTP and would thus result in decreased percentages of players immediately returning to play and later on the day of the injury, as well as increased days out before being cleared to RTP.

The symptom of headache can be easily illustrated as an example. A team physician or athletic trainer cannot often know if a player has a headache unless he reports it or at least admits to it when questioned. The problem with this explanation is that the data indicate that the most common symptoms, such as headache and dizziness, were not reported at any different frequencies during the two 6-year periods. Photophobia, however, was reported at a higher frequency during the second 6-year period; it is possible that this was due to increased forthrightness of the players or increased questioning about this symptom by team medical personnel rather than an actual increase in the presence of the symptom, as postulated earlier in this discussion. However, if players were more open about reporting their symptoms after MTBI, why was photophobia the only symptom to increase in reported incidence, and why was the incidence of the more common symptoms, such as headache and dizziness, as well as the total number of reported symptoms unchanged? The data are thus inconclusive regarding the possibility that increased player reporting of symptoms can explain the changes in RTP during the second 6-year period.

Physician Management of Concussion

Physician management of players who sustained MTBIs may have changed during the second 6-year period. It is possible that increased league-sponsored education about the diagnosis and treatment of MTBI may have resulted in physicians taking a more cautious and conservative approach to players with MTBI. Increased awareness of MTBI resulting from reading medical journal articles, nonleague-sponsored continuing

Table 6. Initial signs and symptoms for concussed players in National Football League games.^a

	1996-2001		2002-2007		<i>P</i>
	<i>n</i>	%	<i>n</i>	%	
General symptoms	487	61.9	484	63.9	NS
Headache	433	55.0	425	56.1	NS
Neck pain	99	12.6	92	12.1	NS
Nausea	62	7.9	74	9.8	NS
Syncope	13	1.7	22	2.9	NS
Vomiting	9	1.1	7	0.9	NS
Back pain	3	0.4	5	0.7	NS
Seizure	1	0.1	2	0.3	NS
Cranial nerve symptoms	416	52.9	425	56.1	NS
Dizziness	329	41.8	308	40.6	NS
Blurred vision	128	16.3	133	17.5	NS
Vertigo	31	3.9	33	4.4	NS
Photophobia	32	4.1	52	6.9	< 0.05
Tinnitus	21	2.7	14	1.8	NS
Diplopia	16	2.0	21	2.8	NS
Nystagmus	8	1.0	14	1.8	NS
Pupil response	5	0.6	1	0.1	NS
Pupil size	0	0.0	2	0.3	NS
Hearing loss	0	0.0	2	0.3	NS
Memory problems	311	39.5	270	35.6	NS
Retrograde amnesia delayed	142	18.0	110	14.5	NS
Information-processing problems	138	17.5	153	20.2	NS
Attention problems	102	13.0	98	12.9	NS
Anterograde amnesia delayed	74	9.4	69	9.1	NS
Cognitive problems	217	27.6	153	20.2	< 0.05
Immediate recall	201	25.5	139	18.3	< 0.06
Not oriented with time	63	8.0	40	5.3	NS
Not oriented with place	40	5.1	21	2.8	NS
Not oriented with person	23	2.9	15	2.0	NS

(continued)

Table 6. (continued)

	1996-2001		2002-2007		<i>P</i>
	<i>n</i>	%	<i>n</i>	%	
Somatic complaints	158	20.1	174	23.0	NS
Fatigue	71	9.0	88	11.6	NS
Anxiety	41	5.2	27	3.6	NS
Personality change	39	5.0	47	6.2	NS
Irritability	25	3.2	32	4.2	NS
Sleep disturbance	6	0.8	7	0.9	NS
Loss of appetite	2	0.3	4	0.5	NS
Depression	1	0.1	8	1.1	NS
Loss of libido	0	0.0	0	0.0	NS
Total symptoms	2158		2065		
No. of reported cases	623		699		
No. with loss of consciousness	59	9.5	57	8.2	

Table 7. Initial action taken by the team physicians for concussed players in National Football League games.

	<i>n</i>			%		<i>P</i>
	1996-2001	2002-2007	Total	1996-2001	2002-2007	
Return immediately	127	64	191	16.1	8.4	< 0.01
Rest and return	280	289	569	35.6	38.1	NS
Removed	346	384	730	44.0	50.7	< 0.05
Hospitalized	19	21	40	2.4	2.8	NS
Unknown	15	0	15	1.9	0.0	
Total	787	758	1545	100.0	100.0	

medical education, and the influences of media and public attention to the topic may have also had the same result. The similarity in clinical signs and symptoms between the two 6-year periods certainly supports the possibility that it was the physicians' response to the injury, not the injury per se, that changed during the second 6-year period.

Before the 2007 season (the last season of the second 6-year period reported here), the Mild Traumatic Brain

Injury Committee reaffirmed to all NFL team physicians that players with witnessed LOC following concussion should not be cleared to RTP on the day of injury.² However, the previous studies have not defined brief LOC as a risk factor for concussion severity, so it is possible that this confounds the data in the second 6 years, depending on how many of the 57 LOC concussions occurred after the ruling change. Review of data indicates that this has been the practice of NFL team

Figure 1. Percentage of players returning to practice and games after concussion, with and without loss of consciousness (LOC) for the 1996-2001 and 2002-2007 seasons.

physicians for a number of years. A small number of players with brief LOC had returned to play on the day of the injury over the past 12 years without any untoward effect, but players with witnessed clear-cut LOC lasting more than 1 minute had all been removed from play. Compared to players of the first 6-year period who sustained LOC, players of the second 6-year period who sustained LOC were kept out of play for longer periods. This suggests that a more conservative approach to the medical management of these players was present before the reaffirmation statement. It therefore seems unlikely that the reaffirmation statement alone had a significant impact on the RTP data reported here.

Neuropsychological Testing

Another possible factor relating to the changes in RTP data is the effect of NP testing. This certainly did not affect the RTP on the day-of-injury data, because NP testing is not performed

until the day following injury. Although many teams were using NP testing during the first 6-year period, its use became much more widespread throughout the league during the second 6-year period and had become mandatory for all teams as of 2007.

The type of NP testing has also changed during these 12 years, from pencil and paper to computerized administration. The possible effect of these changes on RTP decision making cannot be determined until the results of NP testing during the second 6-year period are reported.

Change in Concussion Incidence

At first glance, the decreased incidence in overall concussion frequency during the second 6-year period may appear to be a direct result of the decreased RTP percentages (immediate and later on the day of the injury) and increased days out following MTBI seen during this period. Closer examination indicates that this is not the case. The only way that decreased RTP percentages or increased median days out could influence an overall decrease in the incidence of MTBI would be by lowering the incidence of repeat injury in players who sustain an MTBI.

The data clearly demonstrate that the incidence of repeat concussions was similar during both 6-year periods. Repeat injuries rarely occurred within the first few weeks following initial injury, and the median interval between initial and repeat concussions was about 1 year.⁶ It is thus unlikely that the modest decreases in RTP on the day-of-the-injury percentages or the increase in days out to a period of less than 1 week (ie, the median and mean duration of days out still result in the player's return to the next game following the injury) could exert a significant effect on the overall concussion incidence, in view of the small numbers of repeat injuries that occurred within the short time following initial MTBI.

Other possible explanations for the changes in overall and position player concussion incidence during the second 6-year period must therefore be considered. If all the incidences had decreased, the present data might merely reflect

Table 8. Average number of symptoms with and without photophobia in the 1996-2001 cohort compared to the 2002-2007 cohort.

Symptoms / Case	n	Mean $\pm$ SD	Median	Min	Max	P
With photophobia						
1996-2001	36	5.58 $\pm$ 2.96	5	2	12	NS, 0.65
2002-2007	63	5.29 $\pm$ 3.05	5	1	13	
Without photophobia						
1996-2001	851	2.63 $\pm$ 2.09	2	0	12	NS, 0.40
2002-2007	791	2.54 $\pm$ 2.22	2	0	15	

decreased reporting of MTBI by players, athletic trainers, and/or physicians. However, the frequency of concussion actually increased in tight ends and the kickoff return units. Discussions with players, athletic trainers, and team physicians indicate that all of them have a heightened awareness of MTBI and the importance of reporting all injuries, thus making it unlikely that they would knowingly fail to report some MTBIs. It is also possible that players were less forthcoming and open about reporting concussions during the second 6-year period despite the educational efforts aimed at increasing their willingness to report these injuries.

Rules of Play

The NFL has promulgated a number of rule changes and increased enforcement of existing rules aimed at protecting players from head injuries. Table 9 lists the changes since 1995. A number of these rule changes were made in 2002 or after. Some of the changes apply to all players during kickoffs and punt returns, where running in the open field can lead to high-speed helmet impacts. The changes are meant to protect defenseless players from unnecessary helmet impacts. These changes could have played a role in the trend toward the overall decreased incidence of MTBI. Other rule changes that apply to specific position players, such as quarterbacks, could have played a role in the trend toward decreased MTBI incidence in certain position players.

Tight Ends

In light of the overall trend toward decreased concussion incidence, one certainly must wonder why the incidence increased in tight ends during the second 6-year period. Tight ends should have benefited from improved safety equipment and rule changes as much as any other nonquarterback position player, yet they sustained significantly more MTBIs during the second 6-year period. It is possible that the changing role of the tight end in modern NFL offensive schema has put them at more risk of sustaining MTBI. Over time, the tight ends have been used more as downfield receivers and less as blockers. They are running at higher speeds and being hit at higher speeds by defensive players, which may have resulted in a higher frequency of high-acceleration head impacts and more MTBIs. The trend toward a decreased incidence of MTBI among wide receivers during the second 6-year period might reflect the fact that tight ends are taking away some of the downfield pass receptions and attempts that used to go to the wide receivers, resulting in a lower number of plays in which wide receivers are exposed to high-speed head impacts from defensive backs vying for the ball or tackling the receiver.

Kickoffs and Punts

The differences in concussion incidence occurring on kickoffs and punts (ie, special teams) between the two 6-year periods are difficult to explain. During the second 6-year period, the

incidence of concussions increased for the players on the kick return units but decreased for the players on the kickoff coverage units. The overall incidence of concussion increased on kickoff plays, indicating that the magnitude of the increased incidence on the return unit outweighed the magnitude of the decreased incidence on the kick coverage unit. Rule changes aimed at limiting head impacts during open-field collisions should have applied equally to players on both kickoff units, as well as to players on the punt coverage and punt return units, yet the incidence of concussions decreased on punting plays and increased on one unit involved in kickoffs but not the other. A new rule limiting wedge blocking on the kickoff return unit went into effect during the 2009 NFL season. It will be interesting to see what, if any, effect this will have on concussion incidence on kickoffs overall and, specifically, the return and coverage units.

Quarterbacks and Defensive Linemen

The trend toward decreased concussion incidence in quarterbacks and the statistically significant decreased concussion incidence in defensive linemen during the second 6-year period are congruous with the overall decreased concussion incidence during this period. As noted previously, specific rule changes aimed at protecting quarterbacks from head impacts may have played a significant role in the lowered incidence of concussions in this group of players. Although there were no rules aimed at protecting defensive linemen from head impacts, this group may have benefited from rule changes aimed at protecting all players.

Summary

There are a number of possible explanations for the changes in the RTP data and the incidence of concussion during the second 6-year period. Multiple factors may have played a role in causing these differences, including the efforts by the NFL, the NFL Players Association, NFL team athletic trainers and physicians, and safety equipment manufacturers to ameliorate the effects of head injury on NFL players.

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The opinions and views presented in this article are those of the authors and not necessarily the National Football League. They are offered as part of an effort to better understand the causes and consequences of playing football on the brain and to lay out what additional efforts are needed to prevent brain injury and improve the health, safety, and welfare of individuals playing football.

Table 9. Rule changes in the National Football League to protect player's from concussion.^a

2009
Eliminated "blindsides" helmet-to-helmet blocks. A blocker may not initiate helmet-to-helmet contact against an opponent if the blocker is moving toward his own end line and he approaches the opponent from behind or from the side.
Eliminated initial contact to the head of a defenseless receiver. It is unnecessary roughness if the initial force of the contact by a defender's helmet, forearm, or shoulder is to the head or neck area of a defenseless receiver who is catching or attempting to catch a pass.
Eliminated the "bunch" onside kickoff formation. At least 3 players on each side of the kicker must be lined up outside each inbounds line, one of whom must be outside the yard line number.
Eliminated the "wedge" involving more than 2 players on kickoff returns. An illegal is defined as 3 or more players lined up shoulder-to-shoulder within 2 yards of one another.
2006
Provided protection to the snapper in a defenseless position for field goal attempts and the try by requiring that a defensive player who is within 1 yard of the line of scrimmage at the snap must have his helmet outside the snapper's shoulder pad.
Prohibited kicking teams from "loading up" on one side for a free kick. During a free kick, at least 4 kicking team players must be on each side of the kicker when the ball is kicked.
2005
Prevented unnecessary contact with a kicker/punter throughout a kicking down. An opponent may not unnecessarily initiate helmet-to-helmet contact to the kicker/punter during the kick or during the return.
2002
Prevented unnecessary contact with a kicker/punter throughout a kicking down. An opponent may not unnecessarily initiate helmet-to-helmet contact to the kicker/punter during the kick or during the return. The change also prohibited helmet-to-helmet contact against a quarterback after a change of possession.
1995
Extended protection to defenseless players. Previously, such players were protected against hits delivered by the crown of an opponent's helmet. This was clarified to not only prohibit defensive players from striking virtually defenseless players with the literal top of the helmet but also to prohibit unnecessary and violent punishment by defenders lowering their heads to make forcible contact with the facemask or with the "hairline," or forehead, part of the helmet against an opponent.
Defensive players were prohibited from forcibly hitting an opponent's head, neck, or face with the helmet or face mask, regardless of whether the defensive player also uses his arms to tackle the player by encircling or grasping him or lowering the head and violently and unnecessarily making forcible contact with the "hairline," or forehead, part of the helmet against any part of an opponent's body.
In addition, the following clarifications addressed hits to the head, directly or indirectly: (1) When tackling a passer who is in a virtually defenseless posture, defenders must not unnecessarily or violently throw him down and land on top of him with all or most of the defender's weight. (2) A defensive player must not launch himself (spring forward and upward) into a passer or strike him in a way that causes the defensive player's helmet or face mask to forcibly strike the passer's head, neck, or face, even if the initial contact of the defender's helmet or face mask is lower than the passer's neck. The changes to protect defenseless players were applicable to quarterbacks who are in the act of throwing a pass or who have just thrown a pass. They are considered to be defenseless players.

^aCourtesy of the National Football League.

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