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Video analysis of situations with a high-risk for injury in
Norwegian male professional football; a comparison between 2000
and 2010

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ABSTRACT

Background: A recent study from Norwegian male professional football found that the risk of acute match injuries increased from 2002 to 2007.

Objective: To compare the incidence of incidents with a propensity for injury, from the 2000 season to the 2010 season in Norwegian male professional football using video analysis.

Methods: We conducted video analysis of incidents in Norwegian professional football. An incident was recorded if the match was interrupted by the referee, and the player lay down for more than 15 s, and appeared to be in pain or received medical treatment. We also conducted a video analysis of all player-to-player contact situations occurring during 30 randomly selected matches.

Results: A total of 1 287 incidents were identified during the two seasons. The corresponding rate of incidents was 74.4 (95% confidence interval: 67.3 to 81.5) in the 2000 season and 109.6 (95% confidence interval: 102.3 to 116.9) in the 2010 season, a significant increase from 2000 to 2010 (rate ratio: 1.47, 95% CI: 1.31 to 1.66). We observed a significantly higher rate of opponent-to-player contact and non-contact incidents in the 2010 season, but no change in the proportion of fouls or sanctions awarded by the referee. The rate of player-to-player contact situations in both heading and tackling duels was lower during the 2010 season.

Conclusions: We found an increased rate of non-contact and opponent-to-player contact incidents in both heading and tackling duels in the 2010 season compared to ten years earlier, even if there was no increase in the frequency of player-to-player contact situations.

What this study adds to existing knowledge: We found an increased rate of incidents with a high injury potential in the 2010 season compared to the 2000 season. Little is known regarding the effect of changes in rules and regulations on the risk of injury in male professional football.

How might it impact on clinical practice in the near future: The increased rate of incidents warrants further investigation. We encourage an evaluation of the existing Laws of the Game and their enforcement in order to reduce the risk of injury.

INTRODUCTION

The incidence of time-loss injuries reported from studies in male professional and elite football varies from 20.3 to 34.8 per 1000 player-match hours.[1-6]

Medical staff reporting has shown that between 44% and 59% of all acute match injuries at the club level are caused by player-to-player contact.[2, 6-8] It has previously been argued that sports injury surveillance systems are insufficient to identify the injury mechanisms.[9] Video analysis, on the other hand, represents a useful tool for describing the playing situation and player and opponent behavior when injuries occur.[10] Through video analysis, tackles from the side, late tackles and two-footed tackles have been identified as the tackles with the highest risk of injury, resulting in eversion or inversion sprains of the ankle.[11-13]

A recent study from the Champions League showed that the injury incidence and pattern were stable during seven seasons;[6] in contrast, the incidence of acute match injuries has increased in Norwegian professional football found from 2002 to 2007, suggesting that the style of play may have changed during this period. [14]

The aim of the study was to compare the rate of incidents, situation with a propensity for injury, from the 2000 season to the 2010 season. In addition, we wanted to compare the rate and characteristics of duels between the two seasons.

MATERIALS AND METHODS

Video analysis

We collected videotapes of league matches prospectively throughout the 2000 and 2010 seasons for review by the study group. In 2000, the league was a double round robin competition with home and away matches between 14 teams, resulting in a total of 182 matches. Of these, 174 (96%) were available on video. Of the 174 videotapes, 157 covered the full match, while the remaining 17 covered 73 minutes on average (range: 36-87 min). The total duration of the video recordings was 15 367 minutes; thus, we were able to analyze 256 hours (94%) of a total of 273 hours of football matches in the 2000 season. The 256 hours of match play corresponded to a total of 5 632 player-match hours in the 2000 season. In 2010, 16 teams participated in the Norwegian male professional league. All of the 240 matches were available on video, corresponding to 360 hours of match play and 7 920 player-match hours in the 2010 season.

An *incident* was recorded if the match was interrupted by the referee, and the player lay down for more than 15 s, and appeared to be in pain or received medical treatment.[15, 16] These incidents, including the play leading up to each of them, were transferred to a master video recording. Each incident was classified according to predetermined criteria: the cause (opponent-player contact, teammate-player contact, ball-player contact or non-contact) and body location involved. A duel was defined as a situation where two opponents challenged each other for ball possession; duels were classified as heading duel, tackling duel or other duel (screening or running). We also categorized the referee's decision (no foul, foul for, foul against) and the referee's sanction (no sanction, yellow card or red card). In cases where the referee played "the advantage rule" the decision and

sanction was classified depending on the activity of the downed player and the referees sanction. In addition, incidents affecting the head were classified by cause (head-to-head, arm-to-head, trunk-to-head, leg-to-head in addition head-to-ground/ball/object were listed as head-to-other).

In addition, all tackling incidents were analyzed using variables utilized for video analyses of injuries from three FIFA tournaments.[12] The following variables were included: the direction of the tackle (tackling player approached from the front, the side or from behind the tackled player), action during tackle (one-footed tackle, two-footed tackle, use of arm/hand, upper body contact, clash of heads), tackling mode (tackling player staying on feet, sliding in or jumping vertically). In addition, the study group assessed whether the tackle was late (the tackle occurred after the ball had been passed by the tackled player) and whether the tackling player made contact with the ball (prior to or after initial contact with the tackled player) or not [13] We also classified the tackling incidents in two categories; if the tackled player also tackled, it was indexed an active tackling duel. We defined a passive tackling duel as a situation where the tackled player was unaware of the tackling duel.

We also conducted a video analysis of all player-to-player contact situations between players from opposing teams in 30 matches (14 from the 2000 season and 16 from the 2010 season), irrespective of the consequences of the contact. A player-to-player contact situation was said to occur when there was body contact between two players from opposing teams. We included situations where the players were challenging for ball possession. . We registered the type of duel (tackling, heading and other). For heading duels we included the contact between the two opponent players (trunk-trunk, head-head,

arm-head, leg-head). To select games for analysis in the two seasons, a random draw was made using two bowls with a ball for each team, continuing the draw until we had picked one home match and one away match for each team participating in the league.

The study was approved by the Regional Committee for Medical Research Ethics, and the Norwegian Social Science Data Services.

Statistics

Results are presented as incident rate (incidents/1000 player-match hours). We used a z test and the 95% confidence interval (CI) based on the Poisson model to compare the rate ratio between the 2000 season and 2010 season. Rate ratios are presented with the 2000 season as the reference group. Categorical variables were compared using a χ^2 test. Two-tailed p-value less than 0.05 was regarded as significant.

RESULTS

Video analysis

A total of 1 287 incidents were identified during the two seasons, 419 in 2000 and 868 in 2010. The corresponding overall rate of incidents was 74.4 per 1 000 player-match hours of exposure (95% CI: 67.3 to 81.5) in the 2000 season and 109.6 (95% CI: 102.3 to 116.9) in the 2010 season, an increase from 2000 to 2010 (rate ratio: 1.47, 95% CI: 1.31 to 1.66). We observed a higher rate of opponent-to-player contact incidents and non-contact incidents in the 2010 season. No difference was observed in the rate of incidents caused by teammate-to-player contact or ball-to-player contact (Table 1).

Table 1. Characteristics of incidents (n=1 287) from video analysis of all games (n=414). Rate is reported as the number of incidents per 1000 player-match hours with 95% confidence intervals (CI). Rate ratios between the 2000 and 2010 seasons are shown with 95% CI, with the 2000 season as the reference group.

	2000		2010		2000 vs. 2010
	Incidents	Rate	Incidents	Rate	Rate ratio
Contact opponent	353	62.7 (56.1-69.2)	734	92.7 (86.0-99.4)	1.48 (1.30-1.68)
Contact teammate	18	3.2 (1.7-4.7)	28	3.5 (2.2-4.8)	1.11 (0.61-2.00)
Non-contact	29	5.1 (3.3-7.0)	68	8.6 (6.5-10.6)	1.67 (1.08-2.58)
Contact ball	17	3.0 (1.6-4.5)	32	4.0 (2.6-5.4)	1.34 (0.74-2.41)
Other	2	0.4 (-0.1-0.8)	6	0.8 (0.2-1.4)	2.13 (0.43-10)

Tackling and heading characteristics

We found a higher rate of incidents caused by opponent-to-player contact, both for heading and tackling duels in the 2010 season. We found a higher rate of head, trunk, thigh and lower leg/ankle contact incidents in the 2010 season (Table 2). We found an increased incidence of arm-to-head incidents in the 2010 season. No differences were found in the rate of other mechanisms for head incidents (Table 3).

Table 2. Characteristics of incidents due to opponent-to-player contact (n=1 087) from video analysis of all games (n=414). Rate is reported as the number of incidents per 1000 player-match hours with 95% CI. Rate ratios between incidents in the 2000 and 2010 seasons are shown with 95% CI, with the 2000 season as the reference group.

	2000		2010		2000 vs. 2010
	Incidents	Rate	Incidents	Rate	Rate ratio
Duel type					
Heading duel	87	15.4 (12.2-18.7)	215	27.1 (23.5-30.8)	1.76 (1.37-2.26)
Tackling duel	202	35.9 (30.9-40.8)	437	55.2 (50.0-60.4)	1.54 (1.30-1.82)
Other duel	64	11.4 (8.6-14.1)	82	10.4 (8.1-12.6)	0.91 (0.66-1.26)
Body location					
Head/neck	100	17.8 (14.3-21.2)	226	28.5 (24.8-32.3)	1.61 (1.27-2.03)
Upper extremity	8	1.4 (0.4-2.4)	16	2.0 (1.0-3.0)	1.42 (0.61-3.32)
Trunk	41	7.3 (5.1-9.5)	91	11.5 (9.1-13.9)	1.58 (1.09-2.28)
Lower extremity					
Thigh	12	2.1 (0.9-3.3)	39	4.9 (3.4-6.5)	2.31 (1.21-4.42)
Knee	26	4.6 (2.8-6.4)	49	6.2 (4.5-7.9)	1.34 (0.83-2.16)
Lower leg/ankle	166	29.5 (25.0-34.0)	313	39.5 (35.1-43.9)	1.34 (1.11-1.62)

Table 3. Characteristics of head injury incidents due to opponent-to-player contact from video analysis of all games (n=414). Rate is reported as the number of incidents per 1000 player-match hours with 95% CI. Rate ratios between incidents in the 2000 and 2010 seasons are shown with 95% CI, with the 2000 season as the reference group.

	2000		2010		2000 vs. 2010
	Incidents	Rate	Incidents	Rate	Rate ratio
All head incidents (n=326)					
Head-to-head	46	8.2 (5.8-10.5)	74	9.3 (7.2-11.5)	1.14 (0.79-1.65)
Arm-to-head	35	6.2 (4.2-8.3)	109	13.8 (11.2-16.3)	2.22 (1.51-3.24)
Shoulder-to-head	2	0.4 (-0.1-0.8)	10	1.3 (0.5-2.0)	3.56 (0.78-16)
Trunk-to-head	1	0.2 (-0.2-0.5)	10	1.3 (0.5-2.0)	7.11 (1 (0.91-55)
Leg-to-head	15	2.7 (1.3-4.0)	21	2.7 (1.5-3.8)	1.00 (0.51-1.93)
Other-head	1	0.2 (-0.2-0.5)	2	-	1.42 (0.13-15)
Heading duels (n=237)					
Head-to-head	44	8.2 (5.5-10.1)	68	8.6 (6.5-10.6)	1.10 (0.75-1.61)
Arm-to-head	22	3.9 (2.3-5.5)	84	10.6 (8.3-12.9)	2.72 (1.70-4.34)
Shoulder-to-head	1	0.2 (-0.2-0.5)	6	0.8 (0.2-1.4)	4.27 (0.51-35)
Trunk-to-head	1	0.2 (-0.2-0.5)	2	0.3 (-0.1-0.6)	1.42 (0.13-15)
Leg-to-head	5	0.9 (0.1-1.7)	3	0.4 (0.0-0.8)	0.42 (0.10-1.79)
Other head	1	-	0	-	-

Of the 639 tackling duels, the downed player was passive in 530 (83%) and active in 109 (17%) of the incidents. The characteristics of these 530 passive incidents are listed in table 4. We found an increased rate of tackles from the front, the side and from behind. In addition, we found an increased rate of standing tackles, sliding tackles, and both early and late tackles. There was an increase in the rate of one-footed tackles and upper body tackles; however, no difference was seen for two-footed tackles. We found a higher risk of tackles having contact with the ball prior to player impact and tackles with no ball contact prior to player impact. However, we found no difference in tackles with ball contact after player impact. No differences in tackling characteristics (tackling direction, tackling action, tackling mode, tackling timing and ball contact) were found between the 2000 season and the 2010 season for active tackling duels.

Table 4. Tackling characteristics. Rate is reported per 1000 h of exposure with 95% CI from video analysis of all games (n=414). Rate is reported as the number of incidents per 1000 player-match hours with 95% CI, with the 2000 season as the reference group (n=530).

	2000		2010		2000 vs. 2010
	Incidents	Rate	Incidents	Rate	Rate ratio
Tackle direction					
Front	47	8.3 (6.0-10.7)	139	17.6 (14.6-20.5)	2.10 (1.51-2.93)
Side	84	14.9 (11.7-18.1)	164	20.7 (17.5-23.9)	1.39 (1.07-1.81)
Back	21	3.7 (2.1-5.3)	75	9.5 (7.3-11.6)	2.54 (1.57-4.12)
Tackle action					
One-foot	137	24.3 (20.3-28.4)	333	42.0 (37.5-46.6)	1.73 (1.42-2.11)
Two-footed	4	0.7 (0.0-1.4)	11	1.4 (0.6-2.2)	1.96 (0.62-6.14)
Upper body	9	1.6 (0.6-2.6)	29	3.7 (2.3-5.0)	2.29 (1.09-4.84)
Other	2	0.4 (-0.1-0.8)	5	0.6 (0.1-1.2)	1.78 (0.35-9.17)
Tackling mode					
Feet	62	11.0 (8.3-13.7)	208	26.3 (22.7-29.8)	2.38 (1.80-3.17)
Sliding in	90	16.0 (12.7-19.3)	166	21.0 (17.8-24.1)	1.31 (1.02-1.70)
Jumping	0	-	4	0.5 (0.0-1.0)	-
Tackling timing					
Early	97	17.2 (13.8-20.6)	206	26.0 (22.5-29.6)	1.51 (1.19-1.92)
Late	55	9.8 (7.2-12.3)	172	21.7 (18.5-25.0)	2.22 (1.64-3.01)
Contact ball					
Prior to opponent	27	4.8 (3.0-6.6)	61	7.7 (5.8-9.6)	1.61 (1.02-2.53)
After opponent	21	3.7 (2.1-5.3)	40	5.1 (3.5-6.6)	1.35 (0.80-2.30)
No ball contact	104	18.5 (14.9-22.0)	277	35.0 (30.9-39.1)	1.89 (1.51-2.37)

Referee decision

The characteristics of the referee decisions are shown in table 5. We found no difference in the percentage of free-kicks called for all opponent-to-player contact incidents, passive tackling incidents or arm-to-head incidents. We found no difference in the proportion of yellow or red cards awarded between the two seasons (table 5).

Table 5. Referee decision for different incidents caused by opponent-to-player contact from video analysis of all games (n=414). Proportions were compared using a χ^2 test.

	2000		2010		2000 vs. 2010
	Incidents	Percentage	Incidents	Percentage	p-value
Opponent-to-player contact (n=1087)					
Free kick	169	48%	379	52%	0.25
Sanctioned	52	31%	128	34%	0.49
Passive tackling incidents (n=530)					
Free kick	110	72%	253	67%	0.22
Sanctioned	47	43%	108	43%	0.99
Arm-to-head contact (n=144)					
Free kick	13	37%	38	35%	0.81
Sanctioned	1	83%	6	16%	0.46

Non-contact incidents

Of the 97 non-contact incidents, the thigh (24% in 2000 vs. 39% in 2010) was the body part most commonly involved, followed by the ankle (24% vs. 29%) and the knee (21% vs. 17%). The most common cause of non-contact thigh incidents was running/sprinting and ankle and knee incidents most often occurred during jumping/landing. We found an increased risk of non-contact thigh incidents between the two season (RR: 2.74, 95 CI: 1.20 to 6.30). We observed no other differences between the two seasons for non-contact incidents.

Player-to-player contact situations

During the 30 matches (14 in 2000 and 16 in 2010) a total of 3 526 situations with player-to-player contact were identified, 1787 in 2000 and 1739 in the 2010 season. The corresponding overall rate of contact situations was 3868 (95% CI: 3689 to 4047) in the 2000 season and 3294 (95% CI: 3139 to 3448) in the 2010 season, a reduction from 2000 to 2010 (RR: 0.85, 95% CI: 0.80 to 0.91). We found a lower rate of player-to-player contact in both heading and tackling duels during the 2010 season (table 6).

Table 6. Characteristics of player-to-player contact situations (n=3 526) from video analysis of 32 randomly picked matches. Situations rate is reported per 1000 player-match hours with 95% CI. Rate ratios between the 2000 and 2010 seasons are shown with 95% CI, with the 2000 season as the reference group.

	2000		2010		2000 vs. 2010
	Situations	Rate	Situations	Rate	Rate ratio
Duel type (n=3 526)					
Heading duel	879	1903 (1777-2028)	816	1545 (1439-1652)	0.81 (0.74-0.89)
Tackling duel	637	1379 (1272-1486)	462	1233 (1138-1328)	0.89 (0.80-1.00)
Other duel	271	587 (517-656)	272	515 (454-576)	0.87 (0.74-1.04)

DISCUSSION

The aim of this study was to compare the rate of incidents with a propensity for injury between the 2000 and 2010 seasons in Norwegian male professional football, and to compare duel characteristics between the two seasons. This is the first study to assess changes in duel characteristics over time, and their relationship with injury risk. The main finding was that the rates of opponent-to-player contact and non-contact incidents have increased substantially during the 10-year period.

The observed increase in incidents from the 2000 season to the 2010 season could have been due to an increased incidence of player-to-player contact during each match in the 2010 season. Therefore, we analyzed one home match and one away match for each team participating in the two seasons, 14 games from the 2000 season and 16 games from the 2010 season. We found that the overall incidence of player-to-player contact was lower in the 2010 season compared to the 2000 season, including the incidences of tackling and heading duels. Thus, the increase in the rate of incidents was not due to a general increase in the number of situations with player-opponent contact, but must result from a difference in dueling behavior, i.e. a rougher style of play with more aggressive dueling technique.

A limitation of this study is that we cannot compare the actual injury rate between the 2000 and 2010 seasons; we therefore do not know if the increase observed in the rate of incidents also can be extrapolated to an increase in injury rate. Substantial changes were done in the recording methodology prior to the start of the 2010 season; the recording system used for the Norwegian Elite Football Injury Surveillance System[17] was

adapted to the UEFA Injury Study Protocol.[6] However, it should be noted that we observed a gradual increase in the risk of acute match injuries in the league from 2002 to 2007,[14] suggesting that changes have occurred in the style of play. This seems to be the case, as we observed an increased frequency of duels (heading and tackling duels) leading to stoppage of play. Tackles from all directions, foot tackles and sliding tackles all increased, and there was a higher rate of tackles without ball contact and late tackles. The data also revealed an increased rate of contact incidents affecting the head/neck, trunk, thigh and calf/ankle. Previous studies on injury mechanisms in football have found that most ankle and head injuries are caused by player-to-player contact.[11, 13, 18] For ankle injuries, the most common cause of contact injury is being tackled to the weight bearing limb, involving lateral and medial forces and the tackler staying on his feet.[11-13] The most common causes of head injuries and incidents are typically heading duels, arm-to-head contact, followed by head-to-head contact.[18] It is therefore a concern that we found an increased rate of duel incidents, and that the increased frequency of head incidents was a result of increased arm-to-head contact.

We found no differences in the proportion of free kicks or sanctions for foul play awarded between the two seasons. We had no referee panel for the referees' decisions during matches; thus, we were not able to assess whether the decision called by the referee was correct according to the Laws of the Game. After the 2000 season, the referees' decisions were reviewed retrospectively by a Norwegian FIFA referee panel, concluding that the judgements of the match referee were according to the existing interpretation of the Laws of the Game. It was noted, however, that there might be a need

for stricter rule interpretation or changes to the laws in order to protect players from dangerous play.[17]

A recent study from the UEFA Champions League found that muscle injuries constitute almost one third of all time-loss injuries in male professional football.[19] We found an increased rate of non-contact incidents localized to the thigh. This finding is in correspondence with our 2002-2007 study of injuries in Norwegian professional football, where we observed a trend towards an increased rate of thigh injuries during matches.[14]

Poor video quality has traditionally been a limitation for video analyses of the mechanisms for sports injuries. However, during the recent decade the image quality, the number of camera angles and the resolution has improved. In the 2000 season, 20 (11%) out of 182 matches were broadcast using more than three cameras, whereas in the 2010 season all games were broadcast with at least three cameras, making it easier to capture incidents. Thus, the incident rate might have been underestimated in the 2000 season, leading to an overestimation of the difference between the two seasons.

The increasing rate of injuries found in Norwegian male professional football, and the increasing incidence of incidents found in the present study is alarming. An analysis of 11 859 papers on sports injury prevention across all sports showed that only 0.6% of the articles retrieved focused on rules and regulations, despite the fact that some of these studies showed significant effects on injury risk.[20] In addition, video analyses have shown that referees identify only 40% of head/neck injuries as foul play during FIFA tournaments.[21] It has therefore been suggested that knowledge regarding the injury

potential of arm-to-head incidents is lacking among referees. As a consequence, the International Football Association Board gave referees the authority to sanction potentially injurious fouls, such as intentional elbows to the head, with a yellow or an automatic red card.[22] After this, the incidence of match injuries was significantly lower in the 2010 FIFA World Cup for men compared to the mean incidence found in the three previous World Cups.[23] This was partly explained by stricter rule enforcement. However, the effect of rule changes and a stricter interpretation and enforcement of the Laws of the Game have neither been evaluated through prospective injury surveillance systems nor using systematic video analyses. Our findings indicate that the increased incidence of head incidents can be explained by arm-to-head contact, which should be a concern for all stakeholders in football. We therefore encourage an evaluation of the existing Laws of the Game and their enforcement in order to reduce the risk of injury. A comparison of the incident and injury incidence before and after the introduction of stricter rule enforcement should be addressed in future studies.

In conclusion, we found an increased rate of non-contact and opponent-to-player contact incidents in both heading and tackling duels in the 2010 season compared to ten years earlier, even if there was no increase in the frequency of duels.

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Contributors: JB, RB and TEA contributed to study conception, design, and development of the intervention. JB coordinated the study and managed all aspects, including data collection. JB conducted and initialized the data analyses, which were planned and checked with RB and TEA. JB, RB, and TEA wrote the first draft of the paper, and all authors contributed to the final manuscript. JB and TEA are guarantors

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