How do football injuries occur?

- Video analysis of injury situations and mechanisms in elite football

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Beware of your thoughts
Because they become your words
Beware of your words
Because they become your actions
Beware of your actions
Because they become your habits
Beware of your habits
Because they become your character
Beware of your character
Because it becomes your destiny

- Søren Kierkegaard

Summary

The aims of this study were to develop and test Football Incident Analysis (FIA), a new video-based method for match analysis that combines football-specific and medical information, to achieve a better understanding of the injury mechanisms and events leading up to high-risk situations. Furthermore, we applied FIA to describe the characteristics of injuries and high-risk situations in the Norwegian professional football league. We also sought to assess how violations of the Laws of the Game contribute to injury and to investigate whether the decisions made by referees in high risk situations correctly interpret the rules of football. Finally, we wanted to describe the specific injury mechanisms for ankle and head injuries in elite football.

Paper I: FIA is a video-based method describing incidents that may result in an injury using nineteen variables and categories modified from match analysis. Videos from 35 official Norwegian U-21 matches played from 1994 to 1998 were analysed. Two football experts classified each incident based on predetermined criteria and their results were compared using inter- and intraobserver reliability tests. From the results one can see that the interrater agreement was very good (>0.81) for nine variables and good (0.61-0.80) for ten variables, while intrarater agreement was very good for eighteen variables and good for one variable (paper I). Thus FIA has been developed as a reliable tool to analyse and describe video recordings of incidents and injuries in football-specific terms.

Paper II: Videotapes and injury information were collected prospectively from 174 regular Norwegian professional league matches during the 2000 season. Incidents where the match was interrupted due to an assumed injury were analysed using FIA. Club medical staff prospectively recorded all acute injuries on a specific injury questionnaire. Each incident identified on the videotapes was cross-referenced with the injury reports. Included in the results were 425 incidents, that is, 1.2 incidents per team per match or 75.5 incidents per 1000 player hours. A total of 121 acute injuries were reported from the same matches, that is 0.3 injuries per team per match or 21.5 injuries per 1000 player hours. Of the 121 acute injuries reported to have occurred during the matches, 52 (43%) were identified on video. All of the head injuries, more than half of the knee and ankle injuries and about one-third of the thigh injuries were identified on the videotapes. Although most of the incidents and

injuries seen on video resulted from duels, no single classic playing situation typical for football injuries or incidents could be recognized. However, in most cases the exposed player seemed to be unaware of the opponent challenging him for ball possession.

Paper III: Videotapes and injury information were collected for matches from the male Norwegian professional league during 2000 season. Three referees performed a retrospective blinded evaluation of the incidents. Less than one third of the injuries identified on video and about 40% of the incidents with a high risk of injury resulted in a free kick being awarded by the referee. About one in ten of these situations led to either a yellow or a red card. The agreement between decisions made by the match referee and the expert referee panel was good, that is their decisions agreed in 85% of the situations where injury occurred.

Paper IV: Videotapes and injury information were collected for 313 matches from Norwegian and Icelandic elite football during the 1999-2000 seasons. Video recordings of incidents that resulted in ankle injuries were analyzed and cross-referenced with injury reports from the team medical staff. A total of 46 acute ankle injuries were reported to have occurred, that is 4.5 injuries per 1000 match hours. Of these, 26 (57%) were identified on the videotapes. Two mechanisms thought to be specific to football were found: 1) player-to-player contact with impact by an opponent on the medial aspect of the leg just before or at foot strike, resulting in a laterally directed force causing the player to land with the ankle in a vulnerable, inverted position, and 2) forced plantar flexion where the injured player hit the opponent's foot when attempting to shoot or clear the ball.

Paper V: Videotapes and injury information were collected prospectively for 313 matches played in the Norwegian (2000 season) and Icelandic (1999 and 2000 season) elite leagues. Video recordings of incidents where a player appeared to be hit in the head and the match was interrupted by the referee were analyzed and cross-referenced with reports of acute time-loss injuries from the team medical staff. The video analysis revealed 192 incidents, that is, 18.8 per 1000 player hours. Of the 297 acute injuries reported 17 (6%) were head injuries, which corresponds to an incidence of 1.7 per 1000 player hours (concussion incidence: 0.5 per 1000 player hours). The body part that hit the injured player's head was the elbow/arm/hand in 79 cases (41%), the head in 62 cases (32%) and the foot in 25 cases

(13%). In 67 of the elbow/arm/hand impacts, the upper arm of the player causing the incident was at or above shoulder level, and the arm use was considered to be active in 61 incidents (77%) and intentional in 16 incidents (20%).

Key words: Football, Football incident analysis, video recording, video analysis, match analysis, injuries, incidents, injury mechanisms, biomechanics, footballer's ankle, ankle ligament injury, anterior ankle impingement syndrome, head injuries, concussion.

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List of papers

This thesis is based on the following papers which are referred to in the text by their Roman numerals:

I. Andersen TE, Tenga A, Larsen Ø, Engebretsen L, Bahr R. Football incident analysis (FIA): A new video-based method to describe injury mechanisms in professional football. Br J Sports Med 37: 226-232, 2003

II. Andersen TE, Tenga A, Engebretsen L, Bahr R. Video analysis of injuries and incidents in Norwegian professional football. Br J Sports Med 38: 626-631, 2004

III. Andersen TE, Engebretsen L, Bahr R. Rule violations as a cause of injuries in male Norwegian professional football – are the referees doing their job? Am J Sports Med 32: 62S-68S, 2004

IV. Andersen TE, Flørenes TW, Árnason Á, Bahr R. Video analysis of the mechanisms for ankle injuries in football. Am J Sports Med 32: 69S-79S, 2004

V. Andersen TE, Árnason Á, Engebretsen L, Bahr R: Mechanisms of head injuries in elite football. Br J Sports Med 38:690-696, 2004

Introduction

The extent of football injuries

Football is the most popular spectator sport worldwide. About 200 million licensed players in 204 countries are registered with the Fédération Internationale de Football Association (FIFA), and about 1% participate at the professional level (Stamm and Lamprecht 2001). Top level football is a complex contact sport which requires physical, physiological, psychological, technical and tactical skills of the players (Ekblom 1986; Reilly 2000). Football is responsible for between one-fourth and one-half of all sports-related injuries in Europe (Keller et al. 1987; Høy et al. 1992; Inklaar et al. 1996; Bahr et al. 2001). The risk of injury in professional football is considerable and has been shown to be around 1000 times higher than for industrial occupations generally regarded as high risk (Hawkins and Fuller 1999).

Epidemiology

A study of the incidence of injuries in football is highly dependent upon the definition of injury. In many earlier and recent studies of football injuries, an injury has been defined as any injury occurring during a scheduled match or training session that causes the player to miss at least one training session or match (Ekstrand and Gillquist 1983a; Keller et al. 1987; Nielsen and Yde 1989; Engström et al. 1990; Poulsen et al. 1991; Árnason et al. 1996; Lüthje et al. 1996; Hawkins and Fuller 1999; Hawkins and Fuller 1998). Other recent studies have defined an injury as an incident that leads to the player receiving treatment on or off the pitch, or otherwise is identified as being injured (Hawkins and Fuller 1996). In such an approach not only the injuries that lead to time lost from training or match are recorded, but also all those incidents where the player receives attention or treatment from the medical staff.

The severity of a sport injury has usually been expressed by the number of days absent from training or match-play, typically classified in three categories (Ekstrand and Gillquist 1983a; Inklaar 1994a; Dvorak and Junge 2000). The National Athletic Injury Registration System discriminates between minor (absence of 1 to 7 days), moderately serious (8 to 21 days) and serious injuries (over 21 days or permanent damage) (Alles WF et al. 1979; van Mechelen et al. 1992; Junge and Dvorak 2000). However, Ekstrand and Gillquist (1983b) defines the cut-off slightly differently: less than 1 week is considered minor, 1-4 weeks moderate and more than 4 weeks severe. This definition has been adopted in several subsequent studies (Nielsen and Yde 1989; Engström et al. 1990; Lüthje et al. 1996; Árnason et al. 1996).

Defining injury by the time lost from play criterion depends, even at the elite level, on the frequency of training sessions and games and the intensity and type of training the day after a match. In addition, players respond differently to an injury regarding when they are mentally prepared to participate in training or match. Lewin (1989) defined the player as injured as long as he could not fully participate in training sessions or matches. If any part of the training programme has to be modified for a player, he would be classified as injured, according to this definition. Unfortunately, most studies are not clear about the criteria used to define injury severity according to the duration of absence. In some studies, return to play means just that the player was present at team practices doing whatever drills he was able to take part in. In other studies, fully fit means ready to comply with all instructions given by the coach in training or being fit for match play.

When recording injuries, the method used is also of importance (van Mechelen et al. 1992; Junge and Dvorak 2000). To be able to compare between studies, exact criteria have to be stated when defining an injury. Also, retrospective interviews of players or coaches compared to prospective designed video analysis combined with medical reports from medical staff may lead to widely different results regarding the incidence and severity of injury.

In most studies the injury incidence is expressed as the number of injuries per 1000 hours of football participation. Although the differences in study design and injury definitions mentioned above make a direct comparison between studies difficult, the match incidence of injuries among adult male elite players ranges between 13 and 35 injuries per 1000 hours (Engström et al. 1990; Hawkins and Fuller 1999; Árnason et al. 1996; Lüthje et al. 1996; Inklaar 1994a; Dvorak and Junge 2000).

A considerable number of studies have described the injury pattern (injury type, localization and severity) in football (Inklaar 1994a; Inklaar 1994b; Larson et al. 1994; Árnason et al. 1996; Lüthje et al. 1996; Hawkins and Fuller 1999; Dvorak and Junge 2000).

Inklaar et al. (1994a) concluded from his review of the literature that 61% to 90% of all injuries affected the lower extremities with the thigh (22-24%), ankle (17-19%), knee (15-19%), and lower leg (8-12%) being the most common locations. Furthermore, the distribution of injuries according to body location seems to be unrelated to age (Inklaar 1994a; Dvorak and Junge 2000). However, more upper leg injuries occurred at a high level of play than at lower levels (Inklaar et al. 1996; Dvorak and Junge 2000; Junge and Dvorak 2000). The most common types of injuries in football are strains (35-37%), sprains (20-21%) and contusions (16-24%) (Árnason et al. 1996; Lüthje et al. 1996; Inklaar 1994a; Hawkins and Fuller 1999). Younger players sustain more contusions, whereas a higher percentage of strains has been registered in professional football compared to youth and senior amateur football (Inklaar 1994a; Hawkins and Fuller 1999; Dvorak and Junge 2000). Most football injuries are traumatic with an acute onset, whereas the proportion of overuse injuries varies from 6% to 37% (Nielsen and Yde; 1989Lüthje et al. 1996). There are more overuse injuries among senior players than youth players (Inklaar 1994a; Dvorak and Junge 2000). The proportion of severe injuries in football ranges from 9% to 35% (Ekstrand and Gillquist 1983a; Nielsen and Yde 1989; Engström et al. 1990; Höy et al. 1992; Chomiak J et al. 2000).

The game of football

We have limited knowledge of how football injuries occur and, consequently, how they can be prevented. In order to better understand how football injuries happen, however, a brief description of the development of modern football is necessary. In addition, a description and explanation of some of the football-specific terms and methods most commonly in use among football coaches, players and spectators need to be presented. This may serve as a football-specific introduction leading up to the specific medical aspects on how football injuries occur.

A glance at the history of modern football

Modern football was "invented" in England in the 19th century. In 1863 representatives of the football teams of public schools met in London. This meeting resulted in the founding of a Football Association (FA), and it has been argued that this date marked the birth of modern football (Eisenberg C 2003). In the meeting the FA decided that the ball should be round-shaped and that the players were allowed to pass the ball only with their feet. These rules were decided upon in order to make the players less liable to injuries and hence more suitable for schoolboys, students and professional people. The FA published the rules and took precautions to ensure they were followed by licensing referees and other official experts. The FA introduced limited professionalism in 1885, and three years later a professional league was started (Eisenberg C 2003).

Football, according to English FA rules, was from the 1850's spread to the continent by wealthy members of the aristocracy and upper middle classes who travelled to attractive continental resorts in Germany, Italy and France for recreational purposes. The need for social contact led to the creation of sporting competitions and clubs, and as sporting competitions were public, the locals began to take an interest in them. At the turn of the century and until after the First World War football, mirrored the modern lifestyle of the middle-class elites in the urban centres of Europe and South America (Eisenberg C 2003).

Football was brought to Norway by different British social groups in the 1880's. Until the 1930's football was played mostly by middle class students and merchants' sons. From then on it has been described as a "folk-sport" or "our national summer sport" and now the largest participation sport for males and females in Norway. In the 1970's a new plan for Norwegian football was developed. The intent was to create a platform that enabled Norwegian football to progress to an international level. Subsequently, and partly as a consequence of this priority, semi-professional football was introduced in Norway in 1984 and professional football in 1991 (Goksøyr M and Olstad F 2002b).

Laws of the Game

In the middle of the 19th century the universities of Oxford and Cambridge and other educational institutions began to arrange football matches against each other, and this resulted in a general desire to unify the rules. The representatives of the football teams met in 1863 to make the appropriate agreements (Eisenberg C 2003).

FIFA was founded in Paris in 1904. In 1905, the Executive Committee of the English Football Association Ltd. recognized the National Associations affiliated to FIFA and joined. In the following years, the application of the Laws of the Game as strictly established according to the English model became compulsory. Today, the Laws of the Game are governed by the International Football Association Board (IFAB). The Board discusses and decides proposed alterations to the Laws of the Game (The Fédération Internationale de Football Association (FIFA) 2004).

The Laws of the Game consist of 17 Laws. In Law 5 the authority of the referee is described. His main superior task is to enforce the Laws of the Game. Law 12 deals with fouls and misconducts and how these are penalized. Two disciplinary sanctions can be awarded, cautionable offences that lead to a yellow card and sending-off offences penalized with a red card. A player is cautioned and shown the yellow card if he or she commits any of the following seven offences: 1) is guilty of unsporting behaviour, 2) shows dissent by word or action, 3) persistently infringes the Law of the Game, 4) delays the restart of play, 5) fails to respect the required distance when play is restarted with a corner kick or free kick, 6) enters or re-enters the field of play without the referee's permission, or 7) deliberately leaves the field of play without the referee's permission. A player is sent off and shown the red card if he commits any of the following seven offences: 1) is guilty of serious foul play, 2) is guilty of violent conduct, 3) spits at an opponent or any other person, 4) denies the opposing team a goal or an obvious goal-scoring opportunity by deliberately handling the ball, 5) denies an obvious goal-scoring opportunity to an opponent moving towards the player's goal by an offence punishable by a free kick or a penalty kick, 6) uses offensive or insulting or abusive language and/or gesture, or 7) receives a second caution in the same match.

Although the Laws of the Game seek to protect players from unfair challenges, little is specified in the rules regarding protection from injury. Still, player-to-player contact remains responsible for about 50% of the post match injury reports (Hawkins and Fuller 1999) and foul tackles for nearly 30% of on-pitch and 20% of post match injuries

(Hawkins and Fuller 1998). Being tackled, as opposed to tackling, is responsible for more than 60% of the injuries (Hawkins and Fuller 1999). In several studies at lower levels, foul play has been proposed to be the most important cause of injury (Nielsen and Yde 1989; Lüthje et al. 1996; Peterson et al. 2000; Dvorak et al. 2000). Hawkins & Fuller (1996; 1998) showed that 15-29% of all injuries at the international and professional level resulted from foul play, whereas the rest of the injuries occurred without a free kick being awarded by the referee. In all the non-foul situations in which injury resulted, at least 60% still involved player-to-player contact, and it is not known whether referee performance was adequate in these cases.

The only type of foul play that is clearly defined as serious foul play in the Laws of the Game, and where the player is shown the red card and sent off the field, is a tackle from behind which endangers the safety of an opponent (International Football Association Board (IFAB) 2003). The basis for this amendment of the Laws of the Game regarding tackles from behind has not been clearly stated. It is also vague whether the intention of the Laws of the Game was and is to protect players from injury. However, in the additional instructions for referees, the understanding of serious foul play is underlined. Any player, when the ball is in play, who charges at an opponent in challenging for the ball from the front, from the side or from behind using one or both legs, with excessive force and endangering the safety of an opponent player is guilty of serious foul play (International Football Association Board (IFAB) 2003). One reason for the apparent lack of more specific rules regarding playing situations with a high propensity for injury might be that the specific mechanisms for the most common football injuries are still unknown.

Foul play has been shown to be one of the most important external risk factors in elite football (Lüthje et al. 1996; Hawkins and Fuller 1996; Hawkins and Fuller 1998). Since reduction of foul play and observance of the existing laws of the game have been proposed as possible interventions to reduce the rate of injuries (Dvorak et al. 2000), it is important to assess how the Laws of the Game are being applied by the referees in injury situations. Hence, it is important to find out whether the existing rules are too lenient or whether the referees overlook or misinterpret the rules of the game in situations with a high risk of injury. These and more aspects of the role of foul-play need to be considered thoroughly when looking at how injuries occur. In paper III we have evaluated the decisions and performance of referees in situations with a high risk of injury according to the Laws of the Game.

System of play

Football is a contact sport traditionally played with eleven players on each team. The system of play includes the team formation which is the static position of the players within the team on the field. The players are often grouped into categories such as goalkeeper, defenders, midfield players and attackers. The defenders usually are named full backs (playing on the sides) and central defenders; midfield players are named wing midfielders, inside midfielders and central midfielders; and attackers are named wings and strikers. The number of defenders, midfield players and attackers are dependent on the chosen team formation (Goksøyr M et al. 1997; Larsen Ø 2003).

The team formation has changed a great deal during the last century. In the early times of modern football up to the late 1920's the 1-2-3-5 (one goalkeeper, two defenders, three midfield players and five attackers) playing formation was considered to be the classic. Then a three-back system defined as 1-3-2-5 was introduced and soon became the common style of play for nearly three decades. In the World Championship in Sweden in 1958, Brazil presented the 1-4-2-4 team formation, which marked the trend of playing up to the 1970's. For the last 25 years the team formation has developed further and at the beginning of a new millennium the most common playing formations both among clubs and national teams worldwide are different modifications of the systems 1-4-4-2, 1-3-5-2, and 1-4-5-1 (Goksøyr M and Olstad F 2002a). The Norwegian national teams achieved success playing a 1-4-5-1 formation which was adopted by many of the professional clubs in Norway. Some of the club coaches, however, were influenced by ideas of the continental playing styles or the style of the successful team Rosenborg BK, Trondheim. These teams preferred either a 1-4-4-2 playing formation or a 1-4-3-3 formation (Goksøyr M and Olstad F 2002a).

A game of football is a conflict between two teams with the same ambition - to win the game (Goksøyr M et al. 1997). Therefore, the characteristics of the game of football will produce a high number of player-to-player contact situations. British influences have dominated the development of football in Norway regarding playing style (Goksøyr M and

Hognestad H 1999; Goksøyr M and Olstad F 2002b). The national teams and many Norwegian clubs of recent years have created a tradition built on a rational, goal-oriented approach. The concept of "efficient football" was described by the former successful Norwegian national coach Olsen and his co-workers (Olsen et al. 1994).

The relationship between playing style and injury patterns in football has not been previously described in the literature. Both the system of play and the playing style of a team may affect injury risk, for example through the number of player-to-player contact situations and their localization on the pitch. In addition, the number and type of duels, the running distance covered or the number of sprints performed may influence the injury patterns. A more direct playing style, also called "efficient football" compared to a more possession oriented football, may result in different specific high risk incidents for injury and hence have an effect on how injuries occur in football. In paper I and II the characteristics of playing situations associated to injury in the Norwegian playing style has been assessed.

Video analysis

The ability to control video images with computers has introduced possibilities for enhancing sport-specific feedback and analytical procedures. Franks and Nagelkerke (1988) developed a system to analyse and provide feedback for football making it possible to perform both post- and pre-match analysis on the computer. Recently more and more feedback between coaches and players is given in the form of video tapes (Hughes M 2003). Motion analysis and match analysis are historically the two notational methods most widely in use among coaches and football experts (Reep C and Benjamin B 1968; Reilly T and Thomas V 1976).

Motion analysis

Motion analysis in football using hand notation combined with an audio tape recorder was first described by Reilly and Thomas (1976). They were able to specify in detail the work-rates of players in different positions, distances covered in a game and the percentage of time in different categories of activity, classified according to intensity, duration (or distance) and frequency. A summary of the literature on this topic indicates that outfield players cover 8-13 km during the course of a match, and with as many as one thousand different activities in a game, there is a break in the level or type of activity every six seconds. The overall distance covered by outfield players during a match consists of 24% walking, 36% jogging, 20% cruising sub-maximally (striding), 11% sprinting, 7% moving backwards and 2% moving with possession of the ball (Williams AM et al. 1999; Reilly T 2003). The vast majority of actions are "off the ball", such as a jump for the ball or a tackle of an opponent (Reilly T 2003). The playing positions demand different physical, physiological, technical, and tactical skills, and playing in a certain position may have an impact on the risk of injury and the type of injuries. However, most studies have stated that the field position played does not influence the rate of injury (Ekstrand and Gillquist 1983a; Hoff and Martin 1986; Nielsen and Yde 1989; Engström et al. 1990; Lüthje et al. 1996; Hawkins and Fuller 1998). Hawkins and Fuller (1996) found on the other hand that defenders sustained more injuries than other player positions during the 1994 World Cup. Though in the above study, corrections for relative risk and exposure to different playing actions of all players was not carried out.

Match analysis

Football has a relatively long history of match analysis (Reep C and Benjamin B 1968). Refined computerized methods have been developed for describing playing patterns in football (Hughes M 1988; 1996). Variables associated with each player such as the position in the field of play, the frequency of passing sequences of varying lengths, shots on goal and goals scored are entered into a computer (Hughes M 2003). Two Norwegian coaches taking a scientific approach to football (Olsen and Larsen 1997) developed a modification of the match analysis presented by Reep and Benjamin and extended the number of variables noted. Their advance focused on variables such as patterns of play, team and player performances both in defence and attack, set plays and goal scoring opportunities.

Coaches and managers have over the last decades developed and designed sophisticated computerized notational systems for gathering information. This meticulous method of analysis in football has not yet spilt over to the medical field, although the system may have potential also in the medical analysis of playing situations leading to injury and mechanisms of injury. Most elite football matches are televised, and using video recordings instead of post-injury player interviews can also improve our ability to more objectively identify and understand the injury mechanisms. Since football is a complex game, it is not easily described in quantitative terms, whether attempting to analyse the flow of the game, player-to-player interactions, goal scoring opportunities, or describing injury situations. Nevertheless, video analysis represents an opportunity to analyse and describe the events typically leading up to an injury situation in football-specific terms.

Hawkins and Fuller (1996) analysed video recordings from 44 of 52 matches in the 1994 World Championship and 181 matches at three levels of professional football in England. Furthermore, Rahnama et al. (2002) assessed the exposure of players to playing actions during English Premier League matches and found that more than one third of the playing actions were judged to have some level of injury potential (assessed subjectively on the likelihood of the actions to produce an injury). However, a more detailed description of the characteristics of high-risk playing actions was not provided in these studies.

Since acute injuries occur in a split second, video-based methods that combine football-specific and medical information represent a different approach which has not been used previously. Papers I & II attempt to develop and use this approach to objectively describe the characteristics of injury situations in football.

Causation in football injuries

Understanding the cause of injury is central to advancing knowledge, particularly regarding prediction and prevention (Meeuwisse 1994). In the majority of the published scientific literature regarding football injuries at various levels of play, the focus has been towards collecting basic epidemiologic data. Consequently, the localization, type, and severity of injury, as well as the incidence and risk of injury, have been described in detail. It has been important to establish a broad insight into the problem, both the extent of the problem and the specific injuries related to football. This can be looked upon as the first necessary stage of knowledge to understand how injuries occur in football.

The next level of consideration is to draw attention towards the causes. Elwood (1988) defines a factor as being a cause of an event if its operation increases the frequency of the event; Further, these factors are defined as either sufficient or necessary. Sufficient causal factors, acting on their own, will always produce the outcome while necessary causal factors have to be activated if an outcome shall occur. In other words, a cause is an event, state or action that produces an effect. In medical sciences, a cause is also often referred to as "aetiology, "pathogenesis" or "mechanisms" (Meeuwisse 1994).

Van Mechelen et al. (1992) argue that the risk of injury primarily is dependent on the interaction between athletes, their personal physical or psychological characteristics, and the sports environment. Meeuwisse (1994) argued that a statistically valid factor may or may not be causal. The apparent causal association may still be challenged by systematic error, random error or confounding factors. Therefore, it is important to be aware of the complexity when searching for causal risk factors of athletic injury and to use or establish methods that might assess causal relationships (van Mechelen et al. 1992; Meeuwisse 1994).

Football injuries are likely multi-factorial in aetiology. This implies that one can not separately control each risk factor without looking at combinations of factors that might cause an injury. A multi-factorial model to assess sport injury was presented by Meeuwisse (1994). In this model all factors associated with injury are defined as risk factors and expose the athlete to increased risk of injury. The final link in the chain of events leading to an injury is in his model an inciting event which is associated with the definitive onset of the injury (Meeuwisse 1994).

Two broad categories of sports injuries may be identified which differ in their aetiology. Acute injuries are most often associated with a single traumatic inciting event. An example of such injury in football is a sprained ankle caused by a sliding tackle. Overuse injuries, though, are frequently the result of a repetitive micro-trauma. In the case of an overuse injury, the inciting moment is less apparent. Other types of injuries, such as muscle strains, can be both repetitive and acute in nature. Thus, when analyzing acute injuries in football it seems reasonable to direct more attention towards the inciting playing situation. This analysis may reveal specific actions responsible for specific injury types.

Risk factors

Risk factors can be divided into two main categories: internal or personal risk factors such as age, previous injury, flexibility and somatotype or external (environmental) risk factors such as weather, rule enforcements, playing surface, equipment and the opposing team (van Mechelen et al. 1992). In a review of the literature, the risk of a football injury seems to be influenced by age (Nilsson and Roaas 1978; Ekstrand et al. 1983; Nielsen and Yde 1989; Schmidt-Olsen et al. 1991; Engström et al. 1991; Inklaar 1994a) and level of play (Nielsen and Yde 1989; Ekstrand and Tropp 1990). Older players and players at higher levels of play are at higher risk. However, as a basis for injury prevention in football, more risk factors must be revealed, and also detailed sport-specific information is necessary to understand the causes of injury. Studies on prevention of football injuries are few (Ekstrand et al. 1983; Tropp et al. 1985; Surve et al. 1994; Heidt et al. 2000; Söderman et al. 2000; Junge A et al. 2002). One likely reason for this is the paucity of evidence about the risk factors and mechanisms for football injuries at various levels of play.

Injury mechanisms

There are a limited number of studies focusing on the mechanisms of the most common injuries in football; ankle sprains and contusions, knee sprains and strains to the hamstring and adductor muscles, as well as head injuries (Inklaar 1994a; Tucker 1997; Dvorak and Junge 2000; Kirkendall et al. 2001). All these injury types might have serious long-term consequences for the players. In this thesis we have attempted to provide a more precise description of the mechanisms for ankle and head injuries (paper IV & V).

The majority of football injuries are thought to be unintentional resulting from chance or an error by the player injured or by another player (Reilly 1993). Based on player interviews, contact injuries have been found to represent 40-74% of all acute injuries (Lüthje et al. 1996; Árnason et al. 1996; Hawkins and Fuller 1999) mainly resulting from tackling duels (Lüthje et al. 1996; Árnason et al. 1996; Hawkins and Fuller 1999). Tackling is the mechanism of nearly half of the ACL injuries (Bjordal et al. 1997) and most of the sprain injuries (Árnason et al. 1996) in both the ankle and knee (Nielsen and Yde 1989; Dvorak and Junge 2000). Thus, receiving or making a tackle is thought to result in a substantial injury risk. Non-contact injury mechanisms are thought to account for about half of all acute injuries, with sprinting, shooting or kicking being the most frequent causes reported (Árnason et al. 1996; Hawkins and Fuller 1999).

In most studies, however, the information on injury mechanisms has been collected retrospectively from either the player involved (Ekstrand and Gillquist 1983a; Árnason et al. 1996; Lüthje et al. 1996; Boden et al. 1998; Hawkins and Fuller 1999; Östenberg and Roos 2000; Heidt et al. 2000; Chomiak J et al. 2000) or the team physician (Bjordal et al. 1997). This approach is difficult due to recall bias by either the team physician or the injured player. Also, since injuries happen quickly, often in complex situations, the description of how the injury occurred may be incorrect. In addition, since in many cases two players can be expected to be involved in the injury situation, the injured player may not always be fully aware of what actually caused the injury.

Ankle injuries

Ankle injuries are common among football players accounting for 11-25% of all acute injuries (McMaster and Walter 1978; Ekstrand and Tropp 1990; Larson et al. 1994; Steinbrück 1999; Chomiak J et al. 2000). Since football is a contact sport requiring a variety of skills including running, jumping, passing, shooting, kicking, dribbling, turning, heading and tackling (Ekblom 1986; Inklaar 1994a), the mechanisms may differ from the inversion, plantar flexion and internal rotation injuries typically seen among runners (Garrick J 1977). A small number of studies have documented effective preventive measures for ankle injuries for previously injured male footballers. Ekstrand et al. (1983) showed a significant reduction on the overall number of football injuries, including ankle injuries, through a 7-part prevention program. The risk of ankle injury has been reduced among players with previous ankle injury by using ankle orthoses (Tropp et al. 1985a; Surve et al. 1994) or by participating in balance board training (Tropp et al. 1985a). However, although these studies show promising effects of various generic interventions, prevention programs specific to the sport of football have not yet been developed.

Although the lateral ligament complex is the most commonly injured structure, an injury type thought to be specific to football has also been described. Morris (1943) and later McMurray (1950) originally described a condition referred to as "athlete's ankle" and "footballer's ankle" with talotibial osteophyte formation at the anterior joint capsule. Although this condition—later also referred to as "anterior ankle impingement syndrome"—is a common cause of anterior ankle pain, the exact cause is unknown (Parkes JCH et al. 1980; Ferkel RD and Scranton PE jr 1993; Tol JL et al. 2002). Three different hypotheses have been suggested to explain the formation of osteophytes. First, recurrent maximal plantar flexion and stretching of the joint capsule from repetitive kicking has been suggested to result in traction spurs (McMurray 1950; Biedert R 1991; Massada JL 1991). Second, repetitive kicking of the football ball is hypothesized to cause direct damage to the rim of the anterior ankle cartilage resulting in inflammation, scar tissue formation and calcification (van Dijk CN et al. 1997). Finally, repetitive forced dorsiflexion, causing minor fractures due to impacts between the bone surfaces of the anterior tibia and the talus, has been suggested to cause exostoses to develop on the anterior edge of the tibia and talus (Peterson L and Renström P 2001).

Neither the mechanisms for ankle injury nor the playing situations leading up to ankle injury in football have been described previously. In addition, further risk factors also need to be established in order to target effective preventive programs for ankle injury among footballers. In paper IV we have therefore studied the specific mechanisms for ankle injuries in elite and professional footballers.

Head injuries

Football is the only contact sport that exposes a large number of participants to purposeful use of the head for controlling and advancing the ball. Based on a series of cross-sectional studies (Tysvaer AT et al. 1989; Tysvaer AT and Storli OV 1989; Sortland O and Tysvaer AT 1989; Tysvaer A.T. and Lochen EA 1991). Tysvær et al. (1991) postulated in 1991 that heading the ball could lead to chronic brain injury as seen in boxers (Gronwall D and Wrightson P 1975). Since then, several cross-sectional studies have indicated that football can cause sustained measurable brain impairment, and this has caused significant concerns over the effects of repetitive heading in football (Baroff GS 1998; Matser JT et al. 1998; Matser JT et al. 1999). In response to this, protective headgear has been manufactured for football. Naunheim et al. (2003) showed in a recent experimental study that headgear has little ability to reduce impact when heading, but they suggest that headbands may play a role in attenuating the impact for more forceful blows at the highest speeds.

However, it should be noted that in the absence of longitudinal cohort studies it is not possible to decide whether repetitive heading is the cause of the cognitive deficiencies observed among football players. In a recent review, Kirkendall et al. (2001) state that to date it appears that heading is not likely to be a significant factor, but that the reported deficits are more likely to be the result of accidental head impacts that occur during the course of the matches.

Head injuries account for 4-22% of all football injuries (Sullivan JA et al. 1980; Albert 1983; Sandelin et al. 1985; Lohnes JH et al. 1994; Boden et al. 1998; Powell JW and Barber-Foss KD 1999). This figure, however, incorporates all types of head injuries including facial fractures, lacerations and eye injuries. The rate of brain injuries is difficult to assess due to the problem of defining and grading concussions (Kirkendall et al. 2001). Nevertheless, it appears that the higher the level of play and the more competitive the league, the higher the incidence of concussions (Boden et al. 1998; Powell JW and Barber-Foss KD 1999).

There is limited information on the mechanisms of head injury in football (Kirkendall et al. 2001). Studies based on player reports or reports by team medical personnel show that injuries mainly result from contact with other players (Nielsen and Yde 1989; Árnason et al. 1996; Lüthje et al. 1996; Hawkins and Fuller 1996; Boden et al. 1998; Dvorak and Junge 2000; Peterson et al. 2000). Boden et al. (1998) prospectively studied collegiate female and male players and found that about 70% of the concussions occurred during games and that head-to-head contact was the most frequent mechanism of injury followed by head-to-ground and head-to-other body parts (e.g. foot, knee, elbow). Furthermore, they found that none of the concussions resulted from intentional heading of the ball (Boden et al. 1998).

Acute injuries often occur very quickly, and it may be difficult for players or team medical staff to provide exact information on their mechanisms. A different approach is needed to more precisely describe the circumstances leading to head injuries. Video analysis has been used to study the mechanisms of concussive injury in elite national Australian rules football (McCrory PR and Berkovic SF 2000; McIntosh AS et al. 2000), but this approach has not been used on football. In paper V we therefore examined the mechanisms for head incidents in elite and professional football using video tapes of injury situations.

Aims of the study

1. To develop and test a new video-based method for match analysis Football Incident Analysis (FIA) which combines football-specific and medical information (paper I).
2. To describe the characteristics of injury and high-risk situations in the Norwegian professional football league during one competitive season using FIA (paper II).
3. To evaluate how violations of the laws of the game contribute to injury situations (paper III).
4. To assess the performance of the match referee in situations with a high risk of injury (paper III).
5. To describe the mechanisms for ankle injuries based on video recordings (paper IV).
6. To describe the events leading to head injuries and incidents with a high risk of head injury based on video analysis (paper V).

Methods

Study design

This thesis combines data from injury registration done by the medical staff of the teams involved and from analysis of video recordings from matches played by the same teams. It is based on three data sets covering the Norwegian U-21 team, the Norwegian professional league (the Tippeliga) and the Icelandic elite division (IED).

Study populations and video recordings

In paper I all available video tapes from 35 of 76 (46%) official Norwegian U-21 matches played in the period from February 1994 to June 1998 were traced retrospectively. Of the 35 matches, 17 were official qualification matches for the Olympic Games, European or World championships, and 18 were friendly matches. Of the 35 video tapes, 30 covered the match in full whereas five tapes covered between 50-80 min. The total duration of the video recordings was 3017 min. Information about injuries and incidents was registered for the Norwegian players only.

In papers II-V video tapes and injury information were collected prospectively for the regular Tippeliga matches during the 2000 season (April through October). The regular league is a double round robin competition with home and away matches among 14 teams resulting in a total of 182 matches. All players that had an A-squad contract (approximately 330) participated in the study. Video cassettes from 174 of the 182 matches (96%) were obtained; 157 covered the match in full, whereas for 17 matches the tapes covered 73 min on the average (range: 36 to 87 minutes). The total duration of the video recordings was 15 367 min, which corresponds to 256 hours of football. The total playing time not covered by video tapes was 283 minutes which corresponds to 2% of the matches during the study period.

In papers IV and V video tapes and injury information from the elite division in Iceland during the 1999 and 2000 seasons (May through September) were also included in addition to the data from the Norwegian professional league from the 2000 season. All players that had an A-squad contract (approximately 550) were covered by the study. Video recordings from 313 of 409 (77%) regular matches, 174 of 182 (96%), in Norway (league matches only) and 139 of 227 (61%) in Iceland (121 league and 18 cup matches) were made available for studies IV and V. Of these, 296 covered the match in full whereas for 17 matches the tapes covered 73 min on the average (range: 36 to 87 min). This corresponds to a total of 464.5 match hours, i.e. 10 219 player hours.

The Norwegian Broadcasting Corporation (NRK) and TV2 Norway secured a weekly delivery of DVC pro or Beta SP quality video tapes from the Norwegian professional football league, and Beta SP quality video tapes were in the same way made available from the Sports Department of the Icelandic National Broadcasting Service – Television for the Icelandic matches. National or regional production teams with one to three cameras, including two high-speed slow-motion cameras, were responsible for all recordings in Iceland (papers IV and V) and most of the recordings in Norway (papers II-V). Twenty matches from Norway were live broadcasts covered with six cameras.

Injury registration and definitions

In paper I information on match injuries was obtained through a retrospective review of team medical records by the team physician. All acute injuries had been systematically recorded during training camps and matches since February 1994. For papers II-V, the club medical staff, physiotherapists and/or physicians from all the 14 first league clubs in Norway (papers II-V) and Iceland (papers IV and V) prospectively recorded all acute injuries that occurred during regular league matches.

In papers II-V, a standardized injury questionnaire was used and reports were collected on a monthly basis. The form included information on the date of injury, in which match the injury occurred, as well as the time of injury. Furthermore, the playing position and the injury location were registered, and injuries were classified as contusions, sprains, strains, fractures or lacerations. Finally, each injury received a specific diagnosis using Orchard codes (Orchard 1993).

The same definition of injury was used in all papers (I-V), and an injury was recorded if the player was unable to participate in training or match play for at least one day following the incident (Sullivan JA et al. 1980; Ekstrand and Gillquist 1983a; Albert 1983; Keller et al. 1987). The player was defined as injured until he was able to participate fully in squad training and competitive matches (Lewin 1989; Árnason et al. 1996).

Exposure to training, including type and duration of training, and to matches was recorded on a special form by the club medical or coaching staff.

In all the papers (I-V) injuries were classified as minor when the player could not participate in training or matches for 1-7 days, moderate if absent for 8-21 days, and serious if absent for more than 21 days, according to the National Athletic Injury Reporting System definition (Alles WF et al. 1979; van Mechelen et al. 1992).

Video analysis – identification of incidents

The video tapes were reviewed and all situations where the match was interrupted by the referee, *and* one or more players laid down on the pitch for more than 15 s, *and* the player(s) appeared to be in pain or received medical treatment, were noted as an injury-risk incident. A cut-off of 15 s was chosen because this was a period thought to be long enough to avoid the situations where players intentionally laid down either to rest or to delay playing time. The incidents recorded were then cross-referenced with the injury reports. All incidents relevant to the study in question, including the playing events leading up to each incident, were then transferred to a master videotape for further analysis. In this way, three master video tapes were produced, one with all incidents from the Tippeliga 2000 (paper II), one with ankle injuries from Norway and Iceland (paper IV) and one with head incidents (paper V) from Norway and Iceland.

In paper I the video tapes were reviewed by two experienced physicians, one of them the team physician of the Norwegian U-21-team, whereas in papers II and III the video tapes were reviewed by one physician and one expert on football match analysis.

Football Incident Analysis (FIA) (papers I & II)

The methodology for match analysis which among football coaches is used to evaluate patterns of play, team and player performance (Olsen and Larsen 1997), was modified for this study. Football incident analysis is a video-based method allowing incidents to be described using 19 variables – each with two or more categories (see paper I for details). FIA describes each incident related to the: 1) injured player (e.g. playing position, action with the ball, movement direction and intensity), 2) injured team (e.g. the type of relational skill including all types of passes), 3) opposing team (e.g. degree of defensive team balance), 4) match (e.g. match type, match time, playing phase), 5) attacking play (e.g. attack type, attacking effectiveness), 6) defensive play (e.g. duel type, tackling type, ball winning, 7) playing field (e.g. localization and positioning in 1-on-1 situations) and 8) foul play (e.g. foul type, referee's decision).

Among the different variables analysed, a duel was defined as an incident involving an opponent and classified as heading, tackling, screening, running or other duels (pushing, kicking, obstructing, stepping or colliding). Heading, tackling and screening duels were categorized into active and passive duels. Passive duels were defined as incidents where the exposed player was challenged for ball possession by an opponent, whereas active duels were when the involved player was actively contesting ball possession. Tackling type was subdivided into being tackled (when the involved player was tackled by the opponent from the front, from the side or from behind), or tackling (when the involved player was tackling the opponent from the front, from the side or from behind). A complete FIA was also performed according to the method described in paper I, and the results are presented in paper II.

The playing field was divided into zones and corridors (figure 1). The classification of playing positions was based on a 1:4:5:1- or a 1:4:3:3-formation, whichever was appropriate for the game in question.

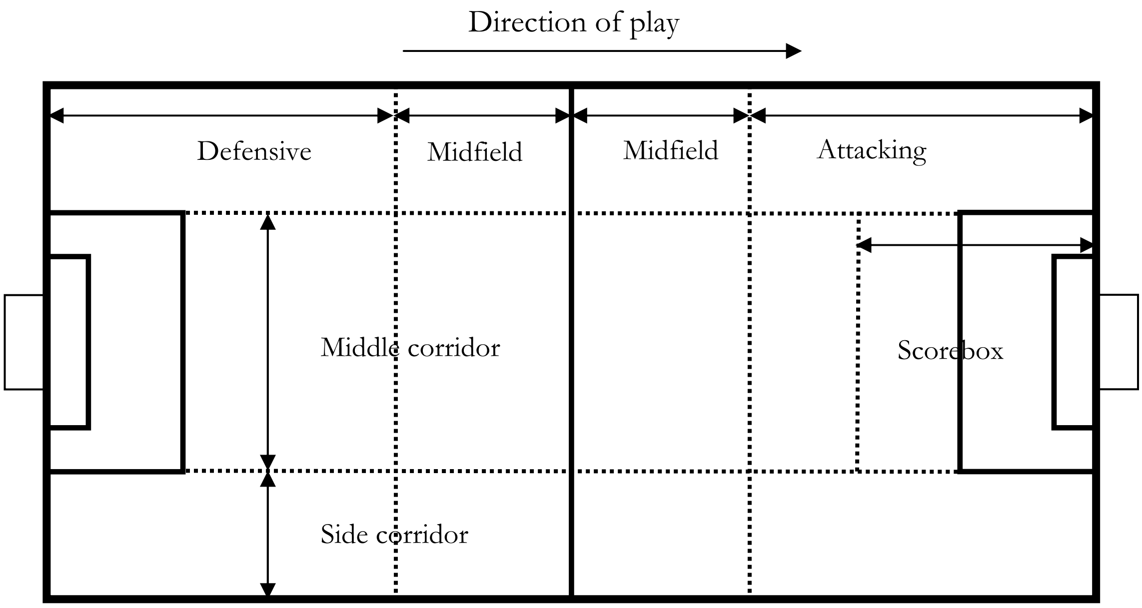

Figure 1: Zones of the playing field

Football incident analysis was used to analyse the incidents recorded from the Norwegian U-21 team (paper I) and the Tippeliga (papers II and III).

In paper I two football coaches with long experience in match analysis reviewed and classified each of the incidents on the master videotape based on predetermined criteria developed during pilot testing, and their results were compared using kappa analysis to determine inter-observer reliability (Altman 1991). One of them re-analysed the tapes three months later to assess the intra-observer reliability.

Video analysis of foul play – paper III

The decision made by the referee for each incident in the Norwegian professional league data set was recorded from the video as no foul or as a free kick for or against the exposed player, and also noted was whether the situation led to a yellow or red card. Three Norwegian FIFA referees with long experience from international football at both the club and national team level independently performed a retrospective blinded evaluation of the incidents based on the master videotape. Blinding was accomplished by editing the video so that the decision of the match referee could not be seen. Their decisions were compared, and in 366 of the 406 incidents a majority agreement could be reached, that is at least two out of three in the referee panel agreed. The performance of the match referee was assessed by comparing his decision with the referee panel decision for these 366 incidents.

Analysis of ankle injuries (paper IV)

Each recording of an ankle injury occurring in the Norwegian professional league and in the Icelandic elite division was edited to include three sequences, i.e. the entire playing situation including the play leading up to the injury at normal speed, one repetition of the injury, and a slow-motion close-up repeat of the injury. The master videotape was analyzed independently by two experienced specialists in sports medicine. Disagreements were discussed in a consensus meeting where the video recordings were re-evaluated and a final decision was made.

A specific ankle questionnaire was developed to describe the injury mechanism and the events leading up to the injury. The questionnaire included the case number and the side injured in each case. Among the different variables analysed (see paper IV for details), the primary injury mechanism was defined as tackling with the foot on the ground, tackling with the foot in the air, clearing or shooting, running or landing after jump. Whether the injured player was tackling an opponent (active) or whether he was being tackled by an opponent (passive) was noted. The tackling types used by the injured player and the opponent were categorized as a sliding tackle, locking tackle of the foot/leg, stepping or kicking. A late tackle was defined when the tackle occurred after the ball had been passed away by the injured player. The main direction of ankle motion at the time of injury was defined as primarily eversion (combination of pronation, external rotation, and dorsiflexion), inversion (supination, internal rotation, plantar flexion) or forced plantar flexion. The point of impact was categorized as the medial side of the ankle or leg, the lateral side of the ankle or leg, or the forefoot of the injured player.

Analysis of head injuries (paper V)

Each recording of a head incident in the Norwegian professional league and the Icelandic elite division was edited to include three sequences, as described before. A head incident was defined as all incidents where the head of the exposed player received an impact. The master videotape with all of the head incidents was analysed independently by three experienced specialists in sports medicine. Disagreements were discussed in a consensus meeting where the video recordings were re-evaluated and a final decision was made.

A specific questionnaire was developed to describe the injury mechanism and the events leading up to the head injury. Among the different variables analysed (see paper V for details) the type of playing action was categorized as a heading duel, being hit by the ball, being kicked by opponent or team mate, a running duel, a tackling duel, positioning/forechecking or as goalkeeping. The body part hitting the head was recorded as the head, elbow, arm/hand, foot, knee, ball, shoulder, alternatively whether the head hit the ground or the goalpost. If the elbow, arm, or hand hit the head, the elbow was categorized as above, at, or under shoulder level, and also noted was whether the elbow/arm/hand use was passive, active or as an intentional strike. Finally, the point of impact was categorized as the face, forehead, side of the head, back of the head, or cervical spine.

Statistical methods

All analyses were performed using the Statistical Package for the Social Sciences (SPSS). Injury and incident rates in papers I-V were recorded as the number of injuries per 1000 player hours or match hours. In papers I and III, kappa correlation coefficients were calculated for inter- and intraobserver agreement (Altman 1991). In paper II the relative risk (RR) for injuries and incidents for specific playing positions was estimated. In addition, injury severity was compared between injuries observed on video and those not identified on video using chi square statistics. A chi square–test with five degrees of freedom was used to test for equality of incidents and injuries between the six 15 minute periods of the match (paper II). In paper V differences in rates between Norway and Iceland were assessed using a poisson regression model, and differences in the proportion of point of impact between two and two body parts were tested by chi square tests.

Ethics

All studies included in this thesis were approved by the Data Inspectorate and the Regional Ethical Committee for Medical Research. The players of the Norwegian professional league and of the elite division in Iceland gave their written consent to participate in the studies allowing a video analysis of injuries to be done and also to provide medical information reported by the medical staff in each club.

Results and Discussion

The magnitude of the problem

During the 35 matches of the Norwegian U-21 international team available for video analysis and the 174 matches in the Tippeliga, a total of 52 and 425 incidents were recorded, respectively (table 1). Of the 52 U-21 incidents, 31% led to acute injuries. Correspondingly, 28% of the incidents resulted in acute injuries in the Tippeliga. Injuries and incidents were distributed evenly throughout the six 15 minute periods of the matches for both the U-21 team and the matches in the Tippeliga.

Table 1: Incidents and acute injuries during matches in Norwegian U-21 international team 1994-1998 and the 2000 Tippeliga season. Acute injuries in the Tippeliga training sessions during the 2000 competitive season (April to October).

	U-21	The Tippeliga 2000	
	Matches	Matches	Training
Number of incidents	52	425	-
Incidence of incidents per team/match	1.6	1.2	-
Incidence of incidents per 1000 player hours	94.0	75.5	-
Number of injuries	16	121	78
Incidence of injuries per team/match	0.5	0.3	-
Incidence of injuries per 1000 player hours	29.0	21.5	1.4

Few studies exist on injuries among international or professional football players. The incidence of time-loss injuries with an acute onset was high – 21.5 injuries for the U-21 team and nearly 30 injuries per 1000 player hours in the Tippeliga. This is higher than some reports from the elite national level (Lüthje et al. 1996; Inklaar 1994a; Dvorak and Junge 2000). The figures corresponds well, however, with some studies (Hawkins and Fuller

1998; Hawkins and Fuller 1999; Dvorak and Junge 2000; Hawkins et al. 2001; Ekstrand J et al. 2004; Junge A et al. 2004b) but are lower than other recent studies on professional and elite players (Árnason et al. 1996; Morgan BE and Oberlander MA 2001; Yoon YS et al. 2004; Junge A et al. 2004a). The definition of injury and interpretation of time loss, however, varies among studies and makes it difficult to compare results directly (Inklaar 1994a; Noyes et al. 1988; Dvorak and Junge 2000; Ekstrand J et al. 2004).

Severity, type of injury and localization

Of the 16 injuries that occurred during the Norwegian U-21 matches, about half of them were classified as serious. Of the 121 injuries during matches in the Tippeliga, 43% were identified on video. Among these, serious, moderate and minor injuries were distributed equally. Sixty-nine injuries were not identified on video. Of these about half were minor and one-fifth serious. Most of the injuries (75-87%) affected the lower extremities in both the Norwegian U-21 and the Tippeliga study populations. Sprains of the ankle or knee were the most common injury types seen on video, whereas muscle strains to thigh or lower leg accounted for nearly half of the injuries reported but were not identified on video (table 2).

Table 2: Severity, type and localization of injury, identified or not identified on video, in Norwegian U-21 international team 1994-1998 and in the 2000 Tippeliga season.
*Contusions include head contusions and concussions.

	U-21	The Tippeliga 2000	
	On video	On video	Not on video
Severity			
-minor	6 (38%)	18 (35%)	35 (51%)
-moderate	3 (19%)	16 (31%)	20 (29%)
-serious	7 (44%)	18 (35%)	14 (20%)
Total	16 (101%)	52 (101%)	69 (100%)
Type of injury			
-strain	-	6 (12%)	31 (45%)
-sprain	5 (31%)	20 (38%)	17 (25%)
-contusion*	4 (25%)	14 (27%)	11 (16%)
-fracture	4 (25%)	4 (8%)	-
-luxation	-	-	1 (1%)
-laceration	3 (19%)	5 (10%)	1 (1%)
-other	-	3 (6%)	8 (12%)
Localization			
-head	3	9	-
-cervical spine/neck	-	1	1
-shoulder incl. clavicula	-	-	1
-arm/hand/elbow	1	-	1
-trunk	-	1	1
-abdomen	-	-	1
-thoracic/ lumbar spine	-	2	4
-groin	-	-	7
-hip	-	1	1
-thigh	1	9	22
-knee	3	11	8
-lower leg	1	6	9
-ankle	4	10	8
-foot/toes	3	2	5
Total	16	52	69

The localization and types of injury found in the two Norwegian study populations correspond closely to other studies (McMaster and Walter 1978; Hawkins and Fuller 1996; Hawkins and Fuller 1998; Hawkins and Fuller 1999; Dvorak and Junge 2000; McGregor and Rae 1995; Junge A et al. 2004a; Junge A et al. 2004b; Ekstrand J et al. 2004)

The present studies are in agreement with numerous other studies showing that football injuries mostly affect the lower extremities (Inklaar 1994a; Tucker 1997; Dvorak and Junge 2000; Morgan BE and Oberlander MA 2001; Junge A et al. 2004a; Junge A et al. 2004b; Ekstrand J et al. 2004). Furthermore, strains and contusions to the thigh, groin and calf, and sprains and contusions to the ankle and knee account for between 60-90% of all football injuries. Although most injuries in the Tippeliga are minor (44%) leading to absence from practice or match-play for less than a week, still about one third are moderate (30%) and 26% serious. Similar figures are found in English professional football (Hawkins et al. 2001), American professional football (Morgan BE and Oberlander MA 2001), and during the World Cup 2002 (Junge A et al. 2004a). However, it appears that the ratio of relatively more serious and moderate injuries compared with minor injuries may be higher than in lower divisions or adolescent football (Inklaar 1994a; Dvorak and Junge 2000). One might expect that the number of minor and slight injuries is underreported in most studies. Nevertheless, the proportion of injuries keeping players from normal participation for several weeks is considerable and very high compared to most other occupations (Drawer S and Fuller CW 2002).

A somewhat unexpected finding in paper II was that, although we performed a thorough review of the tapes, we identified less than half of the acute injuries reported to have occurred during the same matches by the club medical staff. Of the three most common injury types – thigh, ankle and knee injuries – only 58% of the knee injuries, 56% of the ankle injuries and 29% of the thigh injuries were identified on video. Of the 22 thigh injuries not identified on the video, 18 were hamstring strains. In other words, many incidents were not recognized: These included the majority of the hamstrings strains, a significant portion of the knee and ankle injuries and all of the groin injuries. This implies that there was no stoppage in play, and that the player did not go down on the pitch but was able to continue, and was not given treatment until halftime or after the match.

These results suggest that a video analysis alone, as previously used in the studies of Hawkins and Fuller (Hawkins and Fuller 1996; Hawkins and Fuller 1998) and Rahnama et al. (2002), without simultaneous access to medical information from team medical staff, may result in a biased description of how injuries occur (see Methodological considerations).

Developing Football Incident Analysis

The inter-rater agreement was very good (>0.81) for nine variables and good (0.61-0.80) for ten variables. The intra-rater agreement was very good for eighteen variables and good for one variable (paper I). The results showed that FIA has been developed as a reliable tool to analyse and describe video recordings of incidents and injuries in football-specific terms.

Although football is a complex game where it is difficult to classify the various playing actions and player interactions, the inter- and intra-observer reproducibility for the majority of variables developed during pilot testing of FIA was high. Injury mechanisms have traditionally been described in purely biomechanical terms, that are giving an account of the kinematics and kinetics of the injured limb at the time of injury. In our opinion a description of injury mechanisms must include an analysis of the events leading up to the injury situation in order to be complete. FIA has been developed with this in mind – to assess complex interactions leading to situations with a high risk of injury. In this thesis (paper I), we found that incidents not causing an injury resemble those incidents leading to injury. We think that whether an incident leads to an injury or not may be chance. Therefore, the study of incidents gives useful information both regarding the playing events leading to injury and the inciting moment.

The selection of variables and categories was adopted from match analysis methods developed by football experts and modified for the study of injury events in this thesis. The purpose of match analysis traditionally is to study player and team performance regarding tactical, technical and physical aspects (Hughes M 2003). Olsen and Larsen (1997) used sixteen variables to describe match events and individual player performance. Whether the use of a modification of this match analysis method to describe injury situations can be justified may be questioned. The FIA method has been tested to be reasonable accurate. Certainly, there may be other relevant variables or other perspectives describing injury accidents not covered by FIA, and others may chose to develop the method further.

Characteristics of injury situations (FIA results)

The aim of paper II was to describe the events leading to football injuries and incidents in a larger cohort, the Tippeliga, during one competitive season using FIA. However, when comparing the results of FIA of the Norwegian U-21 team (paper I) and the Tippeliga (paper II), the distribution within different categories for each variable is similar.

In spite of a thorough classification of more than 475 incidents (and 68 injuries) (papers I & II), it was not possible to identify just one or only a few characteristic situations that could account for a significant proportion of the injury situations. However, although one – or even a few – typical injury situation(s) could not be recognized, we observed some trends among the incidents and injuries identified on video.

Player position

Of the 52 incidents (16 injuries) that occurred in the Norwegian U-21 team matches, inside left/right midfielders (injuries; (RR=1.3) and wing midfielders (RR=1.7) appeared to be more exposed to both incidents and injuries. In contrast, of the 425 incidents (52 injuries) that occurred in the Tippeliga, strikers appeared to be at higher risk (injuries; RR=2.3), whereas the exposure to injuries varied little between the other static playing field positions. Goalkeepers seem to be less prone to incidents and injuries in both the Tippeliga and the Norwegian U-21 team (figure 2).

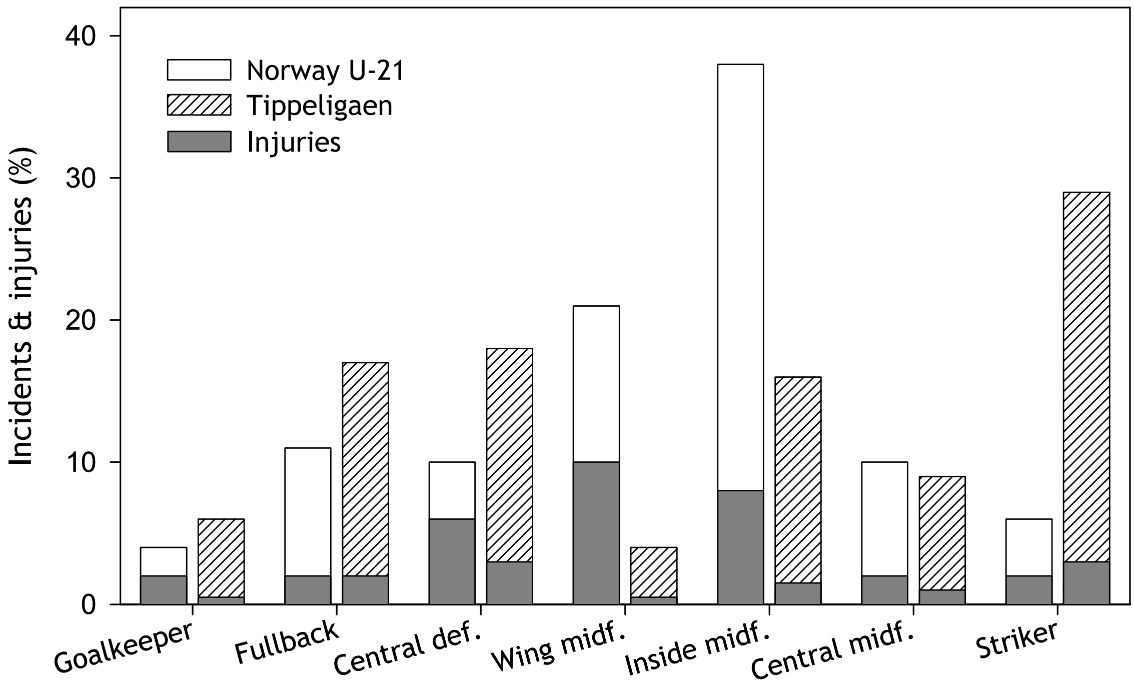

Figure 2: Percentage of incidents and injuries in Norwegian U-21 international team (n= 52 incidents; 16 injuries) and in the Tippeliga (n=425 incidents; 52 injuries) classified according to player position i.e. static positions of players on the field based on playing formations.

In the study of the Norwegian U-21 team (paper I), midfielders accounted for nearly 70% of the incidents. The risk of injury for midfield players was high (n=5; RR=1.4) and was lower among defenders (n=4; RR=0.7), strikers (n=1; RR=0.6) and goalkeepers (n=1; RR=0.7). In the Tippeliga (paper II), strikers appeared to be more exposed to injury situations (RR=2.3). The corresponding figure for central defenders was RR=1.5, fullbacks RR=0.9, inside midfielders RR=1.1, wing midfielders RR=0.2 and goalkeepers RR=0.4. Moreover, a higher percentage of incidents resulted in injuries in the U-21 data set (31%) compared to the Tippeliga (28%).

There are several reasons why these results must be interpreted with caution. First, the number of players in each playing position was an estimate based on the commonly used playing positions for all teams (paper II). Some teams use a fixed playing formation during the game and throughout the season, while other teams vary their playing formation and match strategy depending on the opponent, the result in the game or when a new head coach arrives. Second, the playing positions described are based on static playing formations. The game of football, however, is dynamic, and outfield players are active in different playing positions during the course of a game. When needed, defenders also attack and strikers defend. Third, the results of paper I refer to the Norwegian team only, and their playing formation was constant (1-4-5-1) during the period studied. Their style of play focused on quick breakdown attacks and long forward passes after winning the ball. In line with this, the wing midfielders and the inside midfielders have key roles when switching quickly from defence to attack. This may be the reason why these playing positions seem to be more exposed to incidents and injuries. Finally, the number of injuries in the Norwegian U-21 data set is low, and therefore the figures must be interpreted with caution.

The literature on player field position and injury risk is contradictory with an early study showing that strikers are more likely to sustain an injury (McMaster and Walter 1978), while most later studies have concluded that player position does not seem to influence the injury rate (Ekstrand and Gillquist 1983a; Lüthje et al. 1996; Hawkins and Fuller 1998; Dvorak and Junge 2000; Morgan BE and Oberlander MA 2001). One recent study suggests that players in defensive field positions have the greatest risk of injury (Hawkins and Fuller 1996). The apparent discrepancy between studies could reflect different playing styles between countries and different levels of play. However, at least it seems clear that it is not sufficient to focus on just one or only a few player categories to effectively prevent injuries in football.

Attack type

In the Norwegian U-21 matches, incidents and injuries appeared to occur more frequently during breakdown attacks (38%; of these 10% were injuries) and long attacks, that is possession attacks without a long forward pass (33%; 12% were injuries). In the Tippeliga similar figures were found for incidents occurring during breakdown attacks (47%; 5% were injuries). In contrast, long attacks with possession of the ball seemed to cause more incidents in the Norwegian U-21 matches than in the Tippeliga (22%; 2% were injuries) (figure 3).

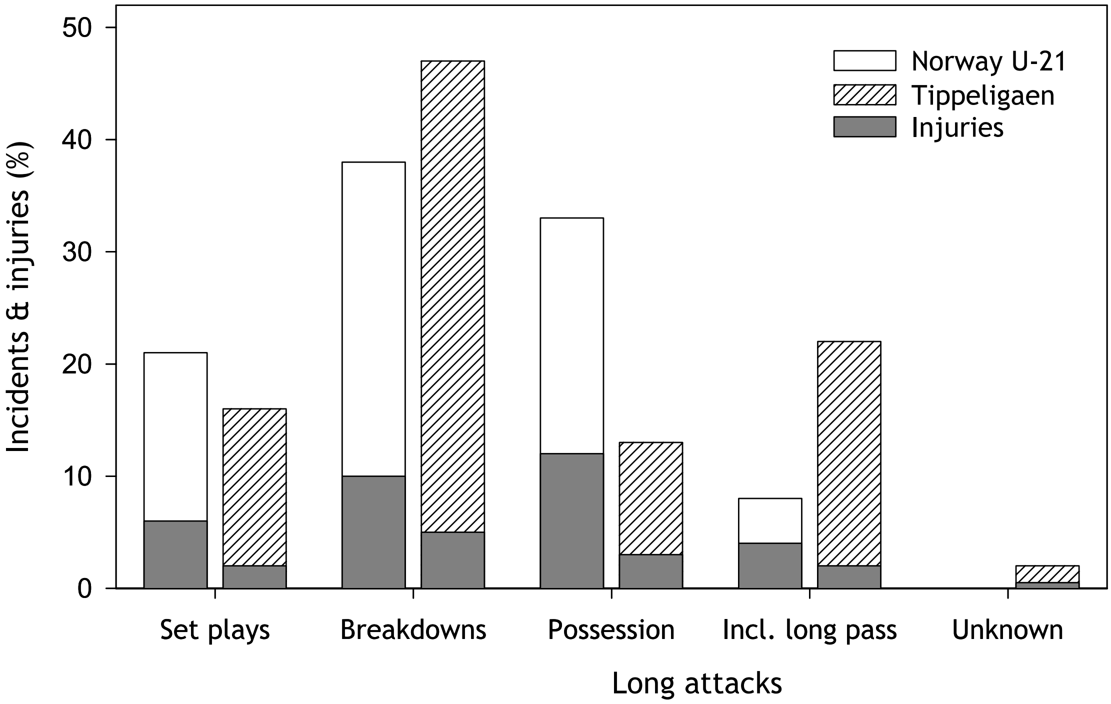

Figure 3: Percentage of incidents and injuries in Norwegian U-21 international team (n=52 incidents; 16 injuries) and in the Tippeliga (n=425 incidents; 52 injuries) classified according to type of attack.

The results of the Norwegian international teams during the last decade have been based on a direct playing style named "efficient football". Quick breakdown attacks and long forward passes after winning the ball are the characteristics of this strategy (Olsen et al. 1994) (see Introduction section). Breakdown attacks seem to cause more injury situations compared with long attacks and set plays in both data sets. Whether this is caused by the typical Norwegian playing style or represents a more general finding regardless of playing style, is difficult to judge. Many of the teams in the Tippeliga have as a consequence of the good results by the Norwegian international teams been influenced by the style of play, while others have developed modifications of the direct playing style and the more possession-oriented continental playing style. FIA or similar approaches have not yet been applied to other more possession-oriented playing styles of other international teams or national leagues to see whether there is a relationship between playing style and injury pattern. Furthermore, the relative risk of the different attack types can not be calculated since we did not collect data on the total number of these attack types during the same matches that did not result in incidents. Rahnama et al (2002), however, calculated the potential for injury of numerous playing actions and found that playing actions with high injury risk were linked to contesting possession such as receiving a tackle or "charge" or making a tackle.

Duels and tackling type

Of the incidents and injuries identified on video in both the Norwegian U-21 matches (paper I) and in the Tippeliga matches (paper II), more than 90% resulted from player-to-player contact in duels, mainly tackling duels (U-21: 80%; the Tippeliga: nearly 50%) and some heading duels (U-21: 10%; the Tippeliga: 20%) (figure 4a). In most of the tackling incidents and injuries in both data sets, the exposed player was being tackled, and mainly the tackle was directed from the side (figure 4b).

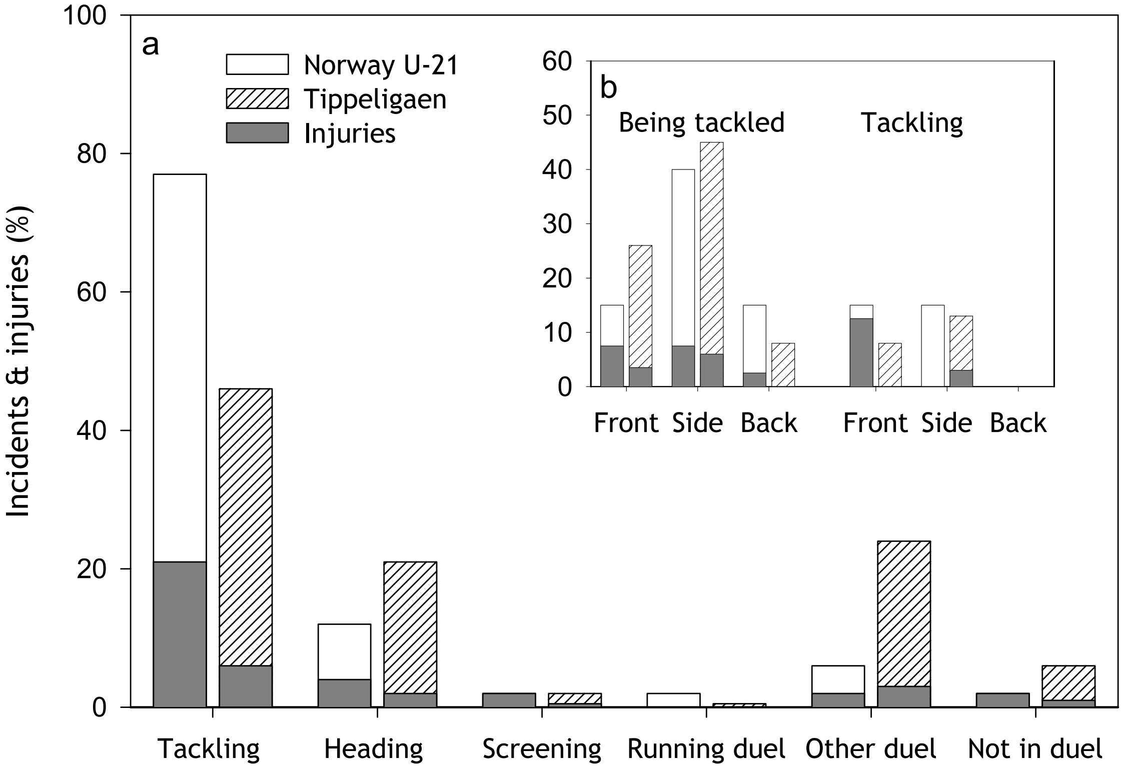

Figure 4a: Percentage of incidents and injuries in Norwegian U-21 international team (n= 52 incidents; 16 injuries) and in the Tippeliga (n=425 incidents; 52 injuries) classified according to type of duel. *4b:* Classified according to type of tackling.

These results match findings from previous studies showing that 44-74% of traumatic injuries result from player-to-player contact (Árnason et al. 1996; Lüthje et al. 1996;

Dvorak and Junge 2000; Junge A et al. 2004a). Similar results were observed by Rahnama et al (2002) who found that all major injuries (that is where the player received treatment and left the field for the remainder of the game) occurred from receiving a tackle or a charge, or from making a tackle. Thus, studying playing events where players contest possession of the ball seems to be the key to understanding injury risk in football. The findings in papers I and II regarding tackling factors correspond well with two recent studies from international football. Fuller et al assessed player error as a causative factor and assessed also the influence of tackle parameters on the propensity for injury (Fuller CW et al. 2004b; Fuller CW et al. 2004c). A tackle in these studies referred to any event that involved physical contact between players while challenging for possession of the ball. They concluded that tackled players received 74% of the post-match medical reports. Furthermore, tackle types with the greatest probability for requiring medical attention were from the side in terms of tackle direction, jumping vertically in terms of tackle mode and clash of heads in terms of tackle action (Fuller CW et al. 2004b; Fuller CW et al. 2004c). The strength of these two studies is that the true exposure to tackles was accounted for and relative risks could be assessed. In contrast, our studies provide a description of the injury situations only.

The laws of the game of football provide limited guidance to referees, players and sporting authorities on how to deal with non-violent tackling that may lead to injury of opponent player other than serious foul play and tackles from behind (International Football Association Board (IFAB) 2003). The results of our studies and recent similar studies may indicate that the statement regarding tackles from behind should incorporate a more specific statement not founded on assumptions of what leads to injury, but based on results from research on the characteristics of injury situations and relative risk of injury from different tackle types.

Player attention

As shown in figure 5, in the vast majority of the incidents and in almost all the injuries, the attention of the exposed player was not directed at the opponent causing the incident but towards the ball on the ground or in the air. The results were parallel for both the Norwegian U-21 team and the Tippeliga teams.

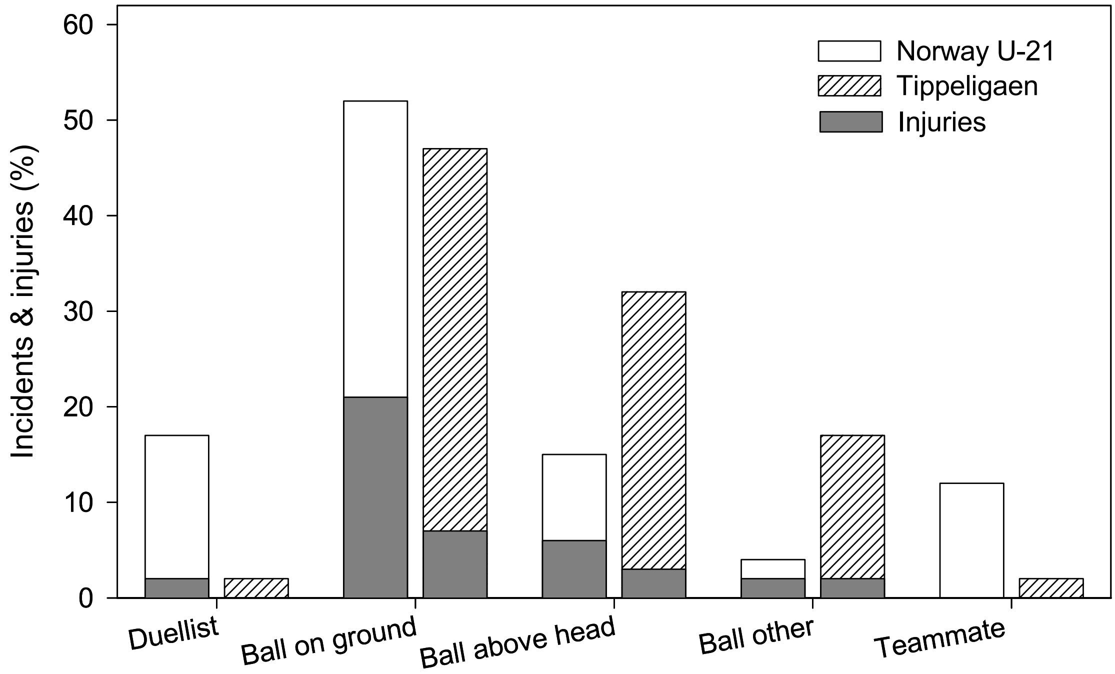

Figure 5: Percentage of incidents and injuries in Norwegian U-21 international team (n= 52 incidents; 16 injuries) and in the Tippeliga (n=425 incidents; 52 injuries) classified according to where the attention of the player appeared to be directed.

The players seem to focus exclusively on the ball and therefore lack the necessary awareness of the primary duellist responsible for the injury event. This factor has not been addressed previously. However, it must be acknowledged that evaluating player attention based on the video pictures can be difficult in some cases.

It may be hypothesized that injuries can be prevented by getting coaches and players to focus on the awareness aspect in duels during training. It may be possible to increase the functional field of vision and be more conscious of the actions of opponents and team-mates in their immediate vicinity. Improved ball-handling skills would also reduce the need to focus on the ball at all times during play.

Foul play and referee performance

One main finding of this study was that less than one third of the injuries identified on video and about 40% of the incidents with a high risk of injury resulted in a free kick being awarded by the referee (figure 6). Furthermore, only about one in ten of the situations led to either a yellow or a red card.

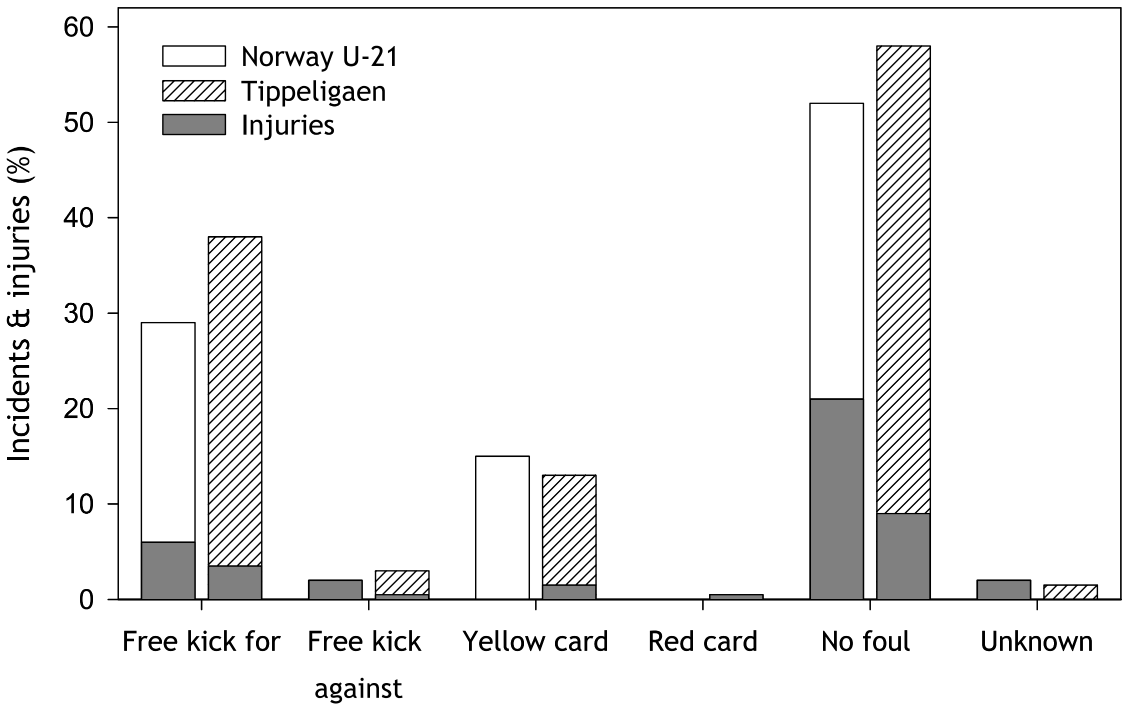

Figure 6: Percentage of incidents and injuries in Norwegian U-21 international team (n= 52 incidents; 16 injuries) and in the Tippeliga (n=406 incidents; 52 injuries) classified according to the referee's decision.

In the Tippeliga, 65% of the heading duels that led to an incident did not cause the referee to call a foul, while 28% led to a free kick for the exposed player. About 40% of the tackling duels did not result in a foul, whereas 55% led to a free kick for the exposed player (table 3).

Table 3: The decision made by the match referee for the incidents (N=406) and the injuries (N=52) related to the types of duels in the Tippeliga. The figures for injuries are shown in parentheses. All of the yellow and the red cards also resulted in free kicks for the exposed player. Other duels: Pushing, kicking, obstructing, stepping and colliding.

	No foul	Free kick for	Free kick against	Unknown	Total	Yellow card[1]	Red card[1]
Heading duel	53 (4)	23 (3)	5 (1)	1 (-)	82 (8)	2 (-)	-
Tackling duel	78 (16)	106 (8)	5 (1)	2 (-)	191 (25)	47 (4)	1 (-)
Screening duels	7 (2)	1 (-)	-	-	8 (2)	1 (-)	-
Running duel	3 (-)	1 (-)	-	-	4 (-)	1	-
Other duel[2]	69 (9)	24 (3)	1 (-)	2 (-)	96 (12)	3 (1)	1 (1)
Not in duel	24 (5)	-	-	1 (-)	25 (5)	-	-
Total	234 (36)	155 (14)	11 (2)	6 (-)	406 (52)	54 (5)	2 (1)

In other words, according to the match referee in the two Norwegian data sets (papers I, II & III), less than half of the incidents (42-47%) resulted from foul play. This is in accordance with a recent study by Fuller et al (2004a) from 12 FIFA tournaments on injuries in general and head/neck injuries in particular. The foul play percentage we observed was higher than previously reported by Hawkins and Fuller (1998; 1996) during the 1994 World Cup (29%) and the 1996 European Championship (28%) for situations leading to on pitch treatment. Studies at lower level adult and youth football also found slightly fewer foul play decisions in situations where injury occurred (Jørgensen 1984; Høy et al. 1992). However, direct comparison between these studies must be interpreted carefully as different definitions of injury have been used. Players have stated that fouls are in some way responsible for 25% to 33% of all injuries (Lüthje et al. 1996; Dvorak and Junge 2000), and referees have considered about one fourth of all traumatic injuries being caused by violation of existing rules (Ekstrand and Gillquist 1983b).

Our findings and results from previous studies show that only about one-third to half of all situations where injury occurs leads to a free-kick for the injured player. In other words, it looks as if the rules of the game do not protect the players from injury or from situations with a high risk of injury. Even if football is a contact sport, too little appears to have been done to avoid the constantly increasing number of injuries, many of them keeping the players at sideline for several weeks.

In one third of the incidents that led to either a free kick for or against the exposed player in the Tippeliga (paper II), a yellow (54 cases) or a red card (2 cases) was also given. However, it should be noted that during the 2000 competitive season in which this video analysis was performed, a total of 468 yellow and 24 red cards were awarded during the 182 regular league matches. This means that only about 10% of the yellow and red cards that were awarded during the season were given in high-risk injury situations detected during our video analysis. Furthermore, a red card was given only for two injury-related offences during the entire season. This indicates that player cautions and expulsions are primarily used for other rule violations than those associated with a high injury risk.

Based on this, it is relevant to question whether the referees interpret and apply the laws of the game correctly in injury situations. The results from study III showed that the agreement between decisions made by the match referee and the expert referee panel was good. Their decisions agreed in 85% of the situations where injury occurred (kappa: 0.65). As seen in table 4, there was no indication that the rule interpretation of the match referee was stricter or more lenient than the referee panel. This was the case for tackling duels (kappa value=0.60) and heading duels (kappa value=0.62) as well.

Table 4: The decision made by the match-referee vs. the majority decision made by the expert referee panel (incidents where 2 out of 3 referees agreed) for 366 incidents (including 46 injuries) observed on video. In 40 cases (including 6 injuries) no majority decision could be reached by the referee panel. The figures for injuries are shown in parentheses.

	Match referee decision				
Referee panel decision	No foul	Free kick for	Free kick against	Yellow card	Red card
No foul	**179 (32)**	7 (2)	1 (-)	2 (-)	-
Free kick for	33 (2)	**80 (5)**	3 (1)	20 (1)	-
Free kick against	1 (-)	-	**3 (-)**	-	-
Yellow card	2 (-)	7 (1)	-	**27 (2)**	-
Red card	-	-	-	-	**1 (-)**

These results are in accordance with a recent study from FIFA tournaments by Fuller et al (2004a) where they used a similar approach. In their study the level of agreement was higher for head/neck injuries compared with injuries in general.

Our study, from the male Norwegian professional league, shows that overall the judgments of the match referees generally seemed to be according to the laws of the game. At least, there was no bias towards too strict or too lenient refereeing. In other words, the performance of the referees, even under difficult match conditions, can be considered acceptable. As a consequence, focus needs to be given towards The Laws of the Game to explore whether they can be formulated in a way that better protects the players from dangerous play. Along with this, proper education and training of referees must continue to maintain and even improve their performance at all levels.

Ankle injuries

Of the 297 acute injuries reported during the 313 matches available on video tape, 46 (15%) were ankle injuries which corresponds to an incidence of ankle injuries of 4.5 per

1000 match hours (paper IV). Of these ankle injuries, 26 (57%) were identified on the video tapes. Of the 26 ankle injuries, twenty-three were classified as sprains and three as contusions.

The frequency of ankle injury and type of injury corresponds well with comprehensive studies from English professional football (Hawkins and Fuller 1998; Hawkins and Fuller 1999; Hawkins et al. 2001; Woods C et al. 2003), American professional football (Morgan BE and Oberlander MA 2001) and Scandinavian elite football (Ekstrand and Tropp 1990; Árnason et al. 1996; Lüthje et al. 1996). The incidence of ankle injury in matches has been estimated between three and nine injuries per 1000 match hours (Giza E et al. 2003).

Ankle injury situations and mechanisms

The video analysis of the 26 ankle injuries showed that the mechanism of injury could be classified into four broad categories: Tackling (n=14), clearing/shooting (n=4), running (n=4) and landing (n=2) (see paper IV for details). Two primary mechanisms were found. The most common occurred in tackling duels where the opponent player hit the injured player on the medial side of the leg causing the player to put weight on an inverted ankle (figure 7). Of these fourteen tackling incidents, eight were categorized as late tackles. Another typical mechanism occurred when the injured player was either clearing or shooting and was blocked by the opponent's foot resulting in a forced plantar flexion (figure 8). Three out of four of these were classified as late tackles.

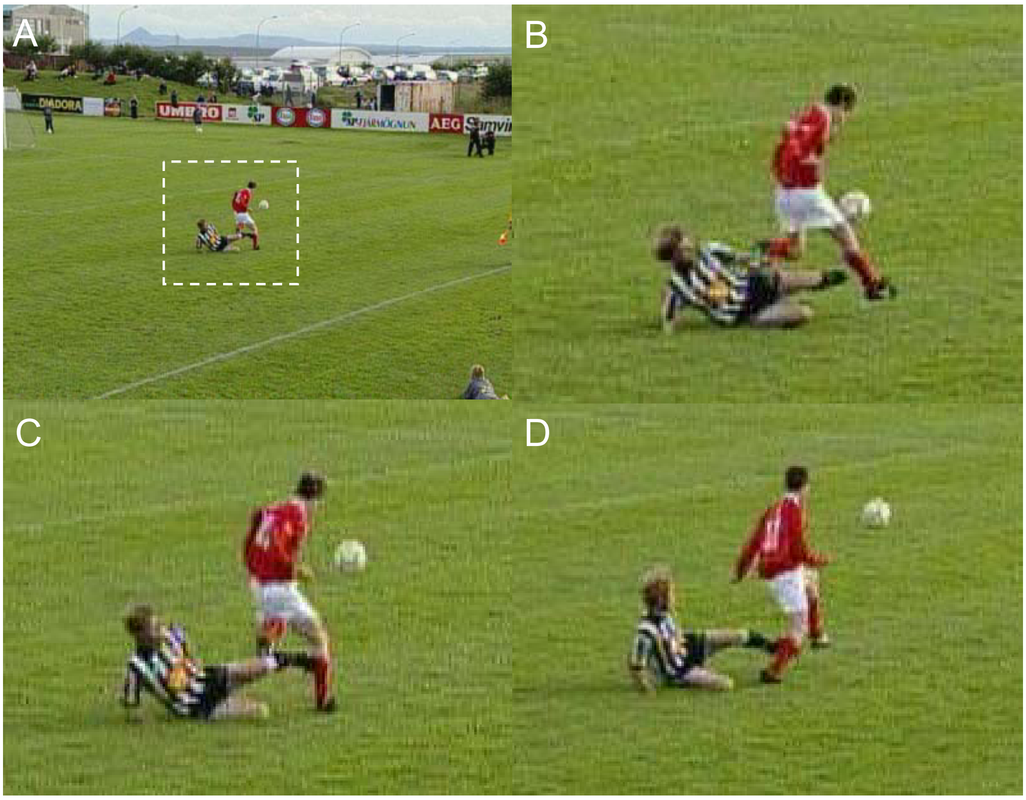

Figure 7: Typical tackling mechanism. A: Overview of the playing situation. B: Close-up of the situation. The injured player (in red) tries to avoid a tackle with the opponent player by jumping over him. C: Opponent player hits the injured player on the medial side of the right leg at the moment the foot hits the ground. He tries to avoid the ankle injury by rotating the knee outwardly. D: The ankle is forced into an inverted position, the knee position can no longer compensate and the player puts his full weight on it.

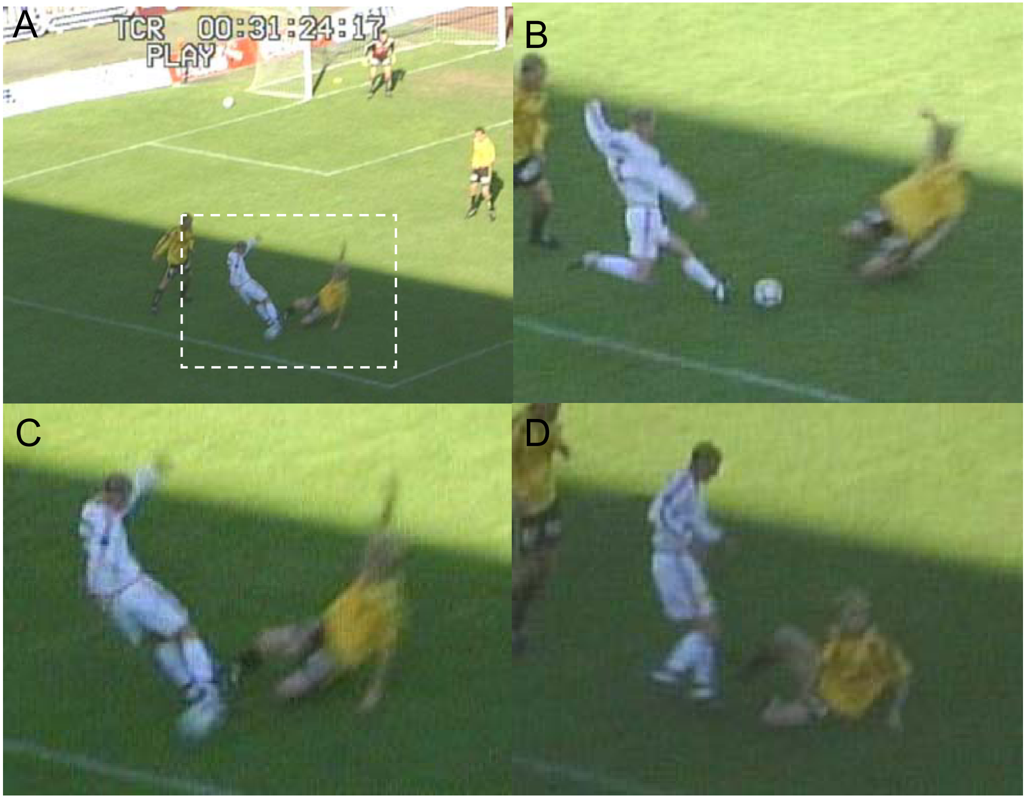

Figure 8: Typical blocking mechanism. A: Overview of the playing situation. B: Close-up of the situation prior to the contact. Player to be injured (in white) prepares to hit the ball with a forceful kick while opponent comes in with a sliding tackle. C: Opponent player hits the ball before the injured player kicks maximally with his right foot, hitting the opponent's foot and getting injured. D: Moment just after the injury.

Video analysis of the injury events and mechanisms for ankle injury in football has only recently been used. In a study by Giza et al (2003), video analysis was applied to assess the relationship between foot/ankle injuries, foul play and type of tackle, and to identify the position of the foot and ankle at the time of injury. Some of their results were comparable to those presented in this thesis (paper IV). First, the foot/ankle injuries often involved a tackle from the side with a medial or lateral tackling force. Second, significantly more injuries resulted in time loss when the limb was weightbearing. Most commonly, the foot and ankle were plantar flexed or neutral in the coronal plane for non-weightbearing limbs at the time of injury. Their results differed, however, with respect to the most common foot and ankle positions at the time of injury for weightbearing limbs. Giza et al. (2003) described the ankle to be pronated/neutral in the sagittal plane. In addition, the most common foot and ankle rotations were found to be external and eversion, while inversion was most common in our study.

Although we had information on the approximate time during the match each ankle injury occurred, we were only able to identify 57% of the acute ankle injuries that were reported by team medical staff to have occurred, even after close scrutiny of the videotapes. This leads us to believe that the remaining 43% of the injuries resulted from minor trauma and mechanisms that may have been different from those identified on video. At least they were more difficult to detect, possibly because they did not result from player-to-player contact or the player did not lie down on the pitch.

The majority (88%) of the ankle injuries we were able to identify on video resulted from contact with an opponent. This is in contrast to a study among youth and adult players participating at various competition levels in one football club in Denmark (Nielsen and Yde 1989). Based on reports from the coaches they found that ankle sprains occurred equally during tackling and running. However, Chomiak et al. (2000), in a prospective cohort study in the Czech Republic, found that 68% of the ankle injuries were due to body contact, and in a recent study among professional English football players 59% of the ankle injuries were reported to be caused by contact mechanisms (Woods C et al. 2003). Although a direct comparison of the results is difficult, since the latter studies were based on player/medical team reports, it seems reasonable to conclude that challenging ball possession is a situation with a high risk for ankle injuries. This is also supported by Giza et al. (2003) and our data.

Based on questionnaire data, inversion of the ankle has been described to be the most frequent injury mechanism for ankle sprains in football (Ekstrand and Gillquist 1983a; Tucker 1997; Chomiak J et al. 2000). Giza et al. (2003) performed video analysis and found that the foot position was pronated/neutral in the sagittal plane for weigtbearing limbs. Ankle inversion torques that result in lateral ligament lesions are thought to arise primarily in situations where the ankle goes through a transition from an unloaded to a loaded condition (Tropp et al. 1985b). Other biomechanical studies have shown that the anterior tibiofibular ligament (ATFL) is the first ligament to be tensed, and so the first to rupture when forced inversion of the ankle occurs (Cawley PW and France EP 1991; Bahr et al.

1998). In other words, the findings from clinical studies, biomechanical research and surgical findings correspond well with the findings in our study (paper IV). The injured player received a laterally directed hit on the medial side of the ankle or lower leg, whereupon he landed in a supinated position which lead to an inversion injury (figure 9).

Figure 9: Typical mechanism for lateral ligament injury in football: Opponent contact to the medial side of the leg causing the player to put weight on an inverted ankle. ©Oslo Sports Trauma Research Center/T. Bolic.

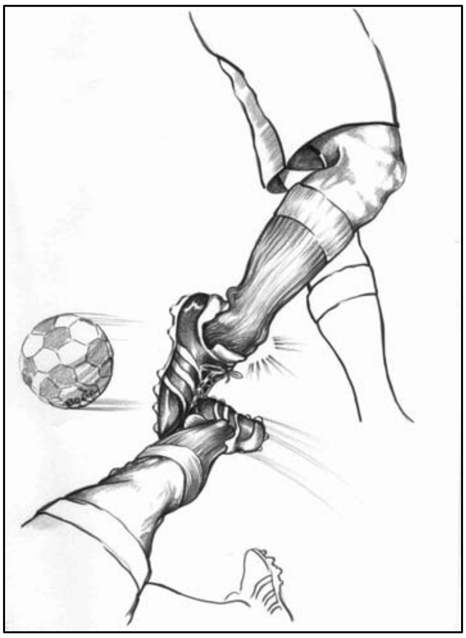

Figure 10: Probable mechanism for development of footballer's ankle. ©Oslo Sports Trauma Research Center/T. Bolic.

In the "clearing or shooting" incidents, the injured player was actively kicking with the foot placed in a forced plantar flexion (figure 10). It may be hypothesized that this is the mechanism whereby footballer's ankle occurs, even if the present number of cases is small. Our video analysis suggests that recurrent maximal plantar flexion and stretching of the joint capsule from repetitive kicking theory (McMurray 1950; Biedert R 1991; Massada JL 1991) may be the cause of 'footballer's ankle'.

Head injuries and incidents

During the 313 matches available on video, 192 head incidents were recorded. Of the 297 acute time-loss injuries reported, 17 (6%) were head injuries which corresponds to an incidence of 1.7 per 1000 player hours. Of the 17 head injuries reported, 16 were identified on video. Five of these were classified as concussions (0.5 per 1000 player hours), two as fractures, four as lacerations, one as a contusion and three as muscular strains to the neck.

The percentage of head injuries in this study (paper V) is in the lower range of previously reported figures (4-22%) (Sullivan JA et al. 1980; Albert 1983; Sandelin et al. 1985; Lohnes JH et al. 1994; Boden et al. 1998; Powell JW and Barber-Foss KD 1999). However, these figures incorporate all types of head injuries including facial fractures, lacerations and eye injuries. Boden et al. (1998), in a study of elite college football players, reported 0.6 concussions per 1000 player hours. This corresponds well with the results in this study (paper V) even if the level of play is different.

We based diagnosis and grading of head injury on reports by the team medical personnel. In the Scandinavian medical tradition, the diagnosis of a concussion has been reserved for cases where a player suffers from loss of consciousness or retrograde amnesia. Diagnosing head injury has always been a challenge for clinicians, and to date there is no universal agreement on the standard definition or nature of concussion (McCrory P 1997; Johnston KM et al. 2001;). However, recently the first steps towards guidelines for the diagnosis and management of the athletes who suffer concussive injuries have been taken (Aubry M et al. 2002). According to these guidelines, concussion may be caused by either a direct blow to the head or elsewhere on the body with an 'impulsive' force transmitted to the head, resulting in an immediate and short-lived functional disturbance of neurological function and a graded set of clinical syndromes that may or may not involve loss of consciousness. This means that some of the facial fractures, lacerations and even contusions to the neck may also have lead to an unrecognized concussive injury. It is therefore reasonable to assume that concussive injuries have been underreported in the present study and that several more may be hidden among the head incidents that were not classified as time-loss injuries. In a recent retrospective study by Delaney et al. (2002), only about one out of five football players realized that he or she had suffered a concussion. Our incidence of concussions therefore represents a minimum estimate—the true incidence of mild brain injury with transient cognitive impairment may be several-fold higher. The present study (paper V) describes the injury situations causing head injury, and this has not been studied previously.

Head injury situations and mechanisms

Of the 192 head incidents (16 injuries) examined on video, the most common injury event was a heading duel (58%). The opponent body part that most often hit the injured player was the elbow (35%) (figure 11). The point of impact on the head was the face in 57% of the cases (9 injuries), the back of the head in 22% (4 injuries), the side of the head in 13% (1 injury), and the forehead in 6% (1 injury).

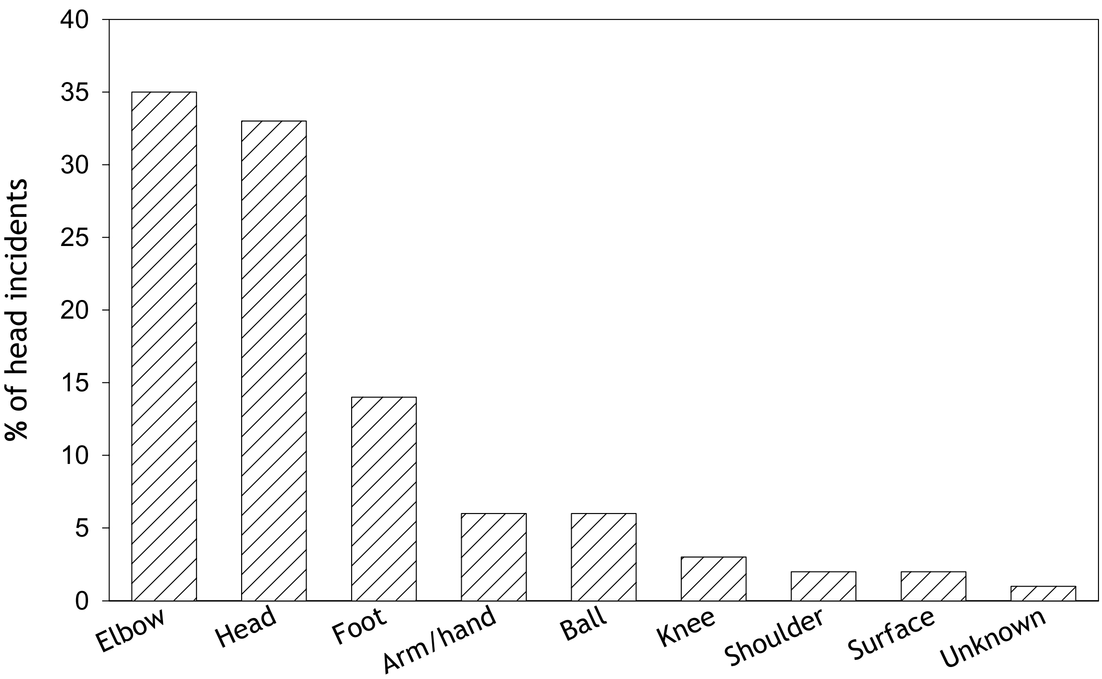

Figure 11: The opponent body part hitting the head of the exposed player (n=192).

Elbow-, arm- or hand-to-head incidents: A total of 43% of the incidents were caused by impact from the upper extremity (figure 12). Of these, in half of the cases the arm of the player causing the incident was above shoulder level and in one third at shoulder level. The use of the elbow was considered to be active in nearly 80% of these incidents and 20% were assessed to be intentional strikes. No foul was called in two thirds of these cases, while a free kick for the exposed player was awarded in 27% of the cases.

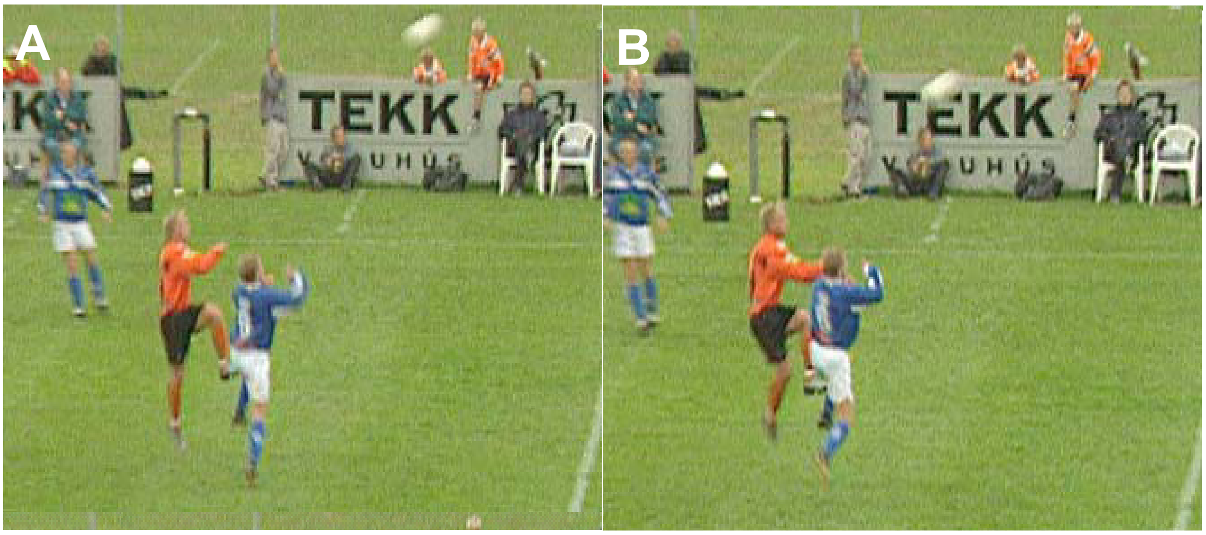

Figure 12: Elbow-to-head incident. A: Close-up just prior to impact. B: Impact, the player in the orange shirt hits the opponent player on the side of the face with his elbow at shoulder level.

Head-to-head incidents: In 33% of the incidents the primary mechanism was head-to-head contact. The point of impact on the injured player was the back of the head in 35% of the cases, the face in 31% and the side of the head in 24% of the cases.

The present video analysis (paper V) clearly shows that the primary mechanism of head injury during matches in elite football is contact between two opposing players during a heading duel. There is no indication that purposeful headings, without opponent contact, leads to injury situations purely through contact with the ball. In addition, the mechanism of head incidents most often involves arm-to-head or head-to-head contact. This result is in some contrast to a prospective study on collegiate men and women where head-to-head contact dominated (Boden et al. 1998). Barnes et al. (1998) and others (Kelly JP and Rosenberg JH 1997) described head-to-ground and head-to-goalpost as the main mechanisms for head injuries in football, whereas we found that these mechanisms are infrequent.

This study (paper V) also showed a difference between the location and mode of impact. In head-to-head incidents the location of impact was most commonly the side or the back of the head, whereas for elbow-, arm- or hand-to-head incidents the face was the location most prone to impact. Moreover, impact to the forehead resulted in very few incidents regardless of the mode of impact. As discussed in more detail below, these findings are important when considering the potential of preventive head gear.

Elbow, arm and hand contact to the head was the most common mechanism observed (figure 11). This is in contrast with findings from English professional football showing that in only one per cent of the match injuries was use of the elbow the injury mechanism (Hawkins et al. 2001). Furthermore, in most of the cases we observed, the elbow was used actively at or above shoulder level, possibly to fend off the opponent and get in position to head the ball (figure 12). In spite of this, in less than one third of the arm-to-head incidents was a foul called. Fuller et al. (2004a) found in a video analysis that the match referees identified 40% of 84 head/neck injuries as fouls in FIFA tournaments. The reasons for this may be that the referees lack knowledge about the injury potential of the elbow-/arm-to-head incidents.

Methodological considerations

Paper I is a retrospective study, and the number of games and thus incidents and injuries are few. There are limitations, which must be taken into account when interpreting the results. Therefore we have not presented data breakdowns for all variables and categories, since there would be very few cases in each category. Also, all the incidents included were taken from one team, the Norwegian U-21 team. However, the main objective of the study (paper I) was to develop FIA as a descriptive tool. In paper II FIA has been applied to Norwegian professional football on a larger sample of incidents involving many teams with different playing styles and playing formations.

Hawkins and Fuller (1996; 1998) conducted the first study of injuries in football using video analysis. One limitation of video analysis is that it can be expected to reveal the more “spectacular” incidents resulting from player-to-player contact. Typically, all of the head injuries were identified (paper II). On the other hand, video analysis alone may overlook a significant number of other acute injury types such as minor muscle strains and ankle sprains. Moreover, overuse injuries with a gradual onset are usually not recognized. Some injury incidents were not recorded on video so the playing events are unknown, however it appears less likely that they resulted from duels, since they did not result in a player going down on the pitch. This suggestion is corroborated by other studies based on player and medical staff reports, showing that about half of all acute injuries were contact injuries (Chomiak J et al. 2000; Hawkins et al. 2001).

The quality of the TV production, e.g. the number of cameras and camera angles used, is obviously also a factor which could prevent us from discovering all injuries or from providing a precise analysis of the events taking place during the course of a match.

The main purpose of using incidents as the unit of analysis was to illuminate the many events and actions with a potential for injury that occur during a game. These playing actions, in particular those linked to contesting possession of the ball, were categorized as having a substantial injury risk, according to Rahnama et al. (2002) in their study of ten games from the English Premier League. However, the validity of using the term incident as the unit of analysis can be questioned. It may be that in some cases players were simply simulating an injury to gain a tactical advantage. However, since as many as one in three incidents resulted in a time-loss injury, it seems that the situations selected were associated with a significant risk of injury. This does not mean that our definition of incident enables us to describe situations taking place during a game that have susceptibility to injury. Most likely this is not the case. We have analysed several of the games in the Tippeliga and found that there are between 120-150 events in each game with player-to-player contact. Yet, only 1% of these resulted in incidents.

In our study, the injury registration was conducted by the team physicians and team physiotherapists. Most diagnoses recorded were primarily based on a clinical examination, and the clinical criteria were dependent on the clinical experience and competence of each individual. Furthermore, only a small proportion of the muscle strains and ligament strains were confirmed by imaging techniques, for instance, by a Magnetic Resonance Imaging (MRI) scan. It is therefore possible that not all diagnoses reported were accurate, even though each injury received a specific diagnosis using Orchard codes (Orchard 1993). Exposure data were collected either by the club physiotherapist or the assistant coach on special forms which were sent in monthly. Exposure to league matches was probably accurate and easy to double-check against league records, whereas the registration of exposure to practice may have been less precise.

In a recent study at Asian tournaments both at the senior and U-20 level (Yoon YS et al. 2004), specially trained observers, all medical doctors, observed the matches live from the VIP-stand. They also had a television nearby with live coverage, and the observers reported all incidents they deemed to cause injuries. Their injury reports were subsequently cross-referenced with the injury reports by the medical staff of each team. The incidence of time-loss injuries in this study was higher compared to our data and among the highest reported in international football. Such a meticulous method of collecting data may have decreased the chances of missing an injury. At tournaments, in particular, combining this method with a thorough video analysis may yield the most precise data collection. For practical reasons, however, such a data collection method is not practical for a national league.

When interpreting the findings in paper III regarding referee performance, there are some methodological issues that need to be addressed. First, although we have used the judgment of the members of the expert panel as the 'gold standard' to assess match referee performance, we cannot be sure that their decisions were correct. In most cases they only had one camera view available, and the view angle of the match referee may have been different from the members of the referee panel in many of the situations. This means that the referee panel may have observed rule violations that the match referee was unable to see, and vice versa. However, in contrast to the match referee they had access to as many slow motion replays as they needed, and this suggests that their decisions may have been correct in most cases. They were also chosen because of their background as FIFA qualified referees with long international experience from the club and national team level, and they were all active referees at the time. All the recordings were edited to blind the panel to the decision made by the match referee, but since the panel members were performing referees, they did lead some of the matches during the 2000 Tippeliga season. Thus, they may have been able to recognize some of the incidents. The referee panel reviewed the incidents independently, and 15% of the incidents had to be excluded from the analysis, in most cases because the recording of the situation was poor from a referee perspective and could not be evaluated by at least two of the panel referees.

Interpretation of the results of papers IV and V must also be performed with certain limitations in mind. First, the video recordings used in this study were from matches only.

Therefore, only mechanisms for ankle and head injuries in match play could be evaluated. However, previous reviews (Ekstrand and Tropp 1990; Inklaar 1994a; Dvorak and Junge 2000) have shown that most football injuries in elite players occur during match play, as was the case in the present studies (paper II, IV and V). Whether the mechanisms for training and match injuries differ is unknown, although we would expect there to be fewer late tackles, elbow-to-head and foot-to-head incidents and less foul play during training compared to match play.

Another constraint is that the assessment of the video recordings was subjective and qualitative, and in some cases based on tapes with less than optimal quality and a limited number of views available. Nevertheless, the main mechanisms for ankle injuries and head incidents appeared to be remarkably consistent between cases, and it was relatively easy to agree on the description and classification of mechanisms.

It should also be noted that the studies involved elite male football players. There may be differences in injury mechanisms between these players and other player populations (e.g. younger players, female players) that warrant attention in future studies.

Even with these limitations, a systematic analysis of injury situations from video would seem to be the obvious approach towards a more detailed understanding of the injury events for football injuries, providing more reliable information than retrospective player or medical staff interviews.

Implications for injury prevention

Over the last years, attention has been directed towards fair play from FIFA and the Union of European Football Associations (UEFA), and fair play is also part of the Champions League concept. Law 12 of the Laws of the Game describes how fouls and misconducts are penalized as well as which offences are cautionable (yellow card) or should lead to being sent off (red card) (International Football Association Board (IFAB) 2003). The rules, however, are not specific regarding situations with a high risk of injury. At least in part, this may be a result of a lack of knowledge about the characteristics of injury mechanisms in football.

Judged from the assessment of the video tapes, there were a number of cases where injuries resulted from late tackles without penalty to the offender. In some cases our impression was that these were intentional, professional fouls. Furthermore, contesting possession of the ball in tackles has been shown in this thesis and other studies (Rahnama N et al. 2002; Fuller CW et al. 2004c) to result in a considerable risk for injury.

The game of football is highly competitive and at the highest professional level the glory and financial benefits from winning are considerable. It may therefore be tempting for players to make use of all means, including intentional fouls, to succeed. The attitude of players in particular, but also coaches, club officials and spectators, need to be taken seriously. While we acknowledge that the task of enforcing the laws of the game is difficult—the match referee not having the benefit of video replay—we would argue that the findings of this thesis show that there is a need for stricter enforcement of the laws of the game. A number of other measures could be potentially effective also, including improved referee training focusing on situations with injury potential and immediate or delayed video review by the match referee in such cases.

Based on the results of this thesis, the most promising strategy to reduce the risk for football injuries would be a more specific wording of The Laws of the Game for instance, regarding late tackles (paper IV) and elbowing (paper V) in duels. Moreover, stricter penalties for this type of rule violations should be considered.

Although some of the elbow-to-head incidents and sliding tackles from the side led to free kicks, and a few even to a yellow or red card, in most cases no foul was called. Our analysis also showed that 20% of the elbow-to-head incidents involved what appeared to be intentional strikes with the arm or elbow. Severe elbow strikes have for some time been penalized by a yellow or red card, but this focus has been mainly directed at playing situations where the arm is used intentionally and hence recognized as unfair playing. This may explain why so few of the cases in this study (paper V) were called as foul play. Thus, the obvious proposals to prevent head injuries are to ban the use of arms at or above the shoulder level in heading duels and to focus on stricter enforcement of the laws of the game in relation to elbow use when challenging for ball possession. This can possibly contribute to a reduction in the number of potentially dangerous elbow-to-head incidents in football.

The present study shows that purposeful heading of the ball was not a cause of incidents and injuries. Moreover, in the majority of the cases, the point of impact was the face, and it is highly unlikely that headgear devices would be able to prevent these injuries. There is an ongoing debate whether heading the ball may lead to brain injury and thus be prevented by a head band. So far no scientific study has been able to show that purposeful heading alone causes concussion or brain injury (Naunheim RS et al. 2003).

Ankle sprains can be prevented (Thacker et al. 1999; Verhagen EA et al. 2001; Bahr 2002). The most important risk factor for ankle injuries is history of a previous ankle sprain (Árnason et al. 2004). The protective effects of taping and bracing have been shown persuasively in football, although only for players with previous ankle injury (Tropp et al. 1985a; Surve et al. 1994).

The present study (paper IV) shows that a significant proportion of ankle injuries are contact injuries resulting from a medial blow to the ankle or lower leg often after a late tackle from the side. In the majority of the cases the mechanism was an inversion trauma. Based on the results from the analysis of injury mechanisms described in this study (paper IV), neither balance training nor can ankle-support be expected to have a protective effect. However, increased neuromuscular control through training or bracing could aid the player in correcting foot position before putting weight on the ankle, at least in some cases. Therefore, based on the results of this study (paper IV), future measures to prevent ankle injuries ought to aim at reducing the number of high-risk situations during match-play.

Some national leagues and international tournaments have introduced post-game video review with strict fines and disqualifications from future games for intentional, serious foul play, and we think this is an important measure to prevent violent conduct. However, it may be that the existing penalty system is too steeply graded. It seems that a free-kick or yellow card has no deterrent effect, since they as a rule have no direct bearing on the result of the game (unless it is a penalty kick or the second yellow card in the same game). In contrast, a red card should have a clear deterrent effect, but as shown in the present study, red cards are not being used to prevent injuries. In many—if not most—cases a red card may have a direct bearing on the result of the game, and therefore the referee may hesitate to expel players, especially early in the game.

We would argue that there is a need for an intermediate disciplinary sanction, sufficiently strict to affect player behaviour significantly, but not so strict that it would be rarely used. We therefore suggest the introduction of timed suspensions of 10 min for active "high elbowing", forceful sliding tackles from the side and other documented playing events with a high propensity of injury. Whether a ten-minute expulsion should replace the yellow card or come in addition to the existing disciplinary sanctions or whether the suspension period should be shorter or longer needs to be discussed further. However, through a ten-minute expulsion, the player(s) and the team(s) will have to expiate the sanction immediately which may influence the actual match, both by "cooling down" the aggressiveness of the players and at the same time also give the fair-playing team an advantage that could even have an impact on the result of the match. We contend that such a change in the laws of football could contribute to a safer sport without detracting from its entertainment value or its spectacular characteristics.

We do not propose FIA as a method to routinely analyse all games of a particular football club or national team, but primarily see it as a research tool. However, FIA has been developed based on an established method for match analysis. Coaches routinely use this method to analyse team and individual performance in games. In addition, a computerized system is available – the Interplay® system – which merges digital video with statistical information about each incident. This tool can also be used to collect data from injury situations. Team doctors can analyse injury situations, both the playing events leading to injury as well as biomechanical aspects. The advantage of the computerized system is that it speeds up the analysis; a trained observer needs only 90 minutes to analyse the performance of one team in one match. Another advantage is that the coaches can use the system to instruct players to perform better through tactical video sessions. Along the same lines, it may be possible to prevent injuries by raising the awareness of potential injury situations among players. The player, coach and team doctor can review video-recordings of duels and other situations by the player to identify those situations during a match with a potential for injury in order to achieve a comprehensive understanding of how such situations occur and discuss strategies to minimize risk or to avoid them.

Conclusions

1. Football Incident Analysis (FIA) is a reliable method which can be used to describe injury situations in football.

2. Fewer than half of the acute time-loss injuries that were reported by club medical staff to have occurred during football matches were identified through a thorough review of video tapes from the same matches. Although an extensive video analysis did not reveal one typical injury situation or pattern characteristic for the events leading to incidents and injuries, some trends were observed. The majority of the injury risk incidents occurred in tackling and heading duels during breakdown attacks, and in almost all cases the attention of the player appeared to be directed towards the ball and not at the opponent challenging for ball possession.

3. Between one-third and one-half of the incidents that either caused injury or had a high potential for injury resulted in a foul awarded by the match referee. A sanction resulting in either a yellow or a red card was given only in about one in ten of the incidents.

4. The interpretation of the rules of the game by the match referees in situations with high risk of injury was in good correlation with the referee expert panel: The match referee was neither too lenient nor too strict in his rule interpretation. In other words, the referees enforce the present rules of the game correctly.

5. The most frequent mechanism for ankle injuries was player-to-player contact with impact on the medial aspect of the lower leg or ankle of the injured player. Most likely, this laterally directed force caused the player to land with the ankle in a vulnerable, inverted position. In addition, we observed a few characteristic cases where the injured player hit his opponent's foot, resulting in forced plantar flexion of the ankle. This mechanism may explain the condition dubbed 'footballer's ankle'.

6. The two most frequent injury mechanisms for head incidents were elbow-to-head and head-to-head contact in heading duels. In the majority of the elbow-to-head incidents the

elbow was used actively or intentionally at or above shoulder level. The face was the main point of impact in the head incidents.

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Paper I

ORIGINAL ARTICLE

Football incident analysis: a new video based method to describe injury mechanisms in professional football

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Objectives: To develop and test a new video based method for match analysis that combines football specific and medical information to achieve a better understanding of the injury mechanisms and events leading up to high risk situations.

Methods: Football incident analysis (FIA) is a video based method describing incidents that may result in an injury using 19 variables and categories modified from match analysis. Videos from 35 of 76 (46%) official Norwegian under 21 matches played from 1994 to 1998 were analysed. Two football experts classified each incident on the basis of predetermined criteria, and their results were compared using interobserver and intraobserver reliability tests.

Results: κ correlation coefficients for interobserver and intraobserver agreement were very good for 63% and 95% and good for 37% and 5% of the variables respectively. Fifty two incidents were recorded (1.6 incidents per team per match or 94 per 1000 player hours), and 16 (31%) led to injuries (0.5 injuries per match or 29 injuries per 1000 player hours). FIA results showed that 28 incidents occurred while attacking in midfield zone 2 or the attacking zone, and 24 took place while defending in the defensive zone or midfield zone 1. Midfielders were exposed in 67% of the incidents, mainly in breakdown attacks or during long attacks by the opposing team. Of the 28 incidents during offence, only one was classified as having great potential to score a goal. Most incidents (70%) were the result of tackling duels both in the offensive and defensive playing phases. Of the 21 offensive incidents resulting from tackling duels, in 19 cases the exposed player was unaware of the tackling (passive duellist).

Conclusions: This study shows that football incident analysis is a potentially valuable tool for understanding the events leading up to injuries in football.

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Football is the most popular spectator sport in the world. About 250 million licensed players in 204 countries are registered with the Fédération Internationale de Football Association (FIFA), and about 1% participate at the professional level.[1] Football is a complex contact sport that demands physical, physiological, technical, and tactical skills,[2 3] and the risk of injury is considerable. Although differences in study design and injury definitions make a direct comparison between studies difficult, the incidence of injuries among adult male players has been estimated to range between 10 and 35 per 1000 game hours.[4–6]

Although a considerable number of studies have described the incidence and injury pattern (injury type, localisation, and severity) in football,[4 5 7 8] much less is known about risk factors and injury mechanisms. The risk of injury seems to be influenced by age,[4 9–11] sex,[4 12 13] and level of play.[11 14] However, as a basis for injury prevention, more sport specific information is necessary to understand the causes of injury in football.

It is therefore surprising that only six studies on injury prevention in football have been published to date. Ekstrand *et al*[15] showed a significant reduction in the overall number of football injuries through a seven part prevention programme. In a study of female high school students, seven weeks of preseason conditioning significantly reduced the total number of injuries.[16] The risk of ankle injury has been reduced among male players with previous ankle injury by using ankle orthoses[17 18] or balance board training.[18] The rate of injuries to the anterior cruciate ligament was significantly decreased through a programme of balance board training,[19] whereas no significant effect was observed on the rate of injuries to the lower extremities in female players after the introduction of a programme with 10–15 minutes of daily balance board training.[20] However, although these studies show promising effects of various generic interventions, prevention programmes specific to the sport of football have not yet been developed.

In order to suggest preventive strategies specific to football, it is necessary to have detailed information on the injury mechanisms involved. It is difficult to determine injury mechanisms on the basis of information from injured players because of recall bias. As most elite football matches are televised, the use of video recordings instead of player interviews may improve our ability to more objectively identify and understand the injury mechanisms. However, describing the injury situations is a difficult task, because football is a complex game not easily described in quantitative terms, whether attempting to analyse the flow of the game, player to player interaction, or goal scoring opportunities. Nevertheless, video analysis may provide an opportunity to analyse and describe the events typically leading up to an injury situation in football specific terms. Hawkins and Fuller[21] analysed video recordings from 44 of 52 matches in the 1994 World Championships and 181 matches at three levels of professional football in England. They found that 15–29% of incidents resulted from foul play. However, their analysis was limited to studying the effect of foul play on injury risk, and they had limited access to medical information from the incidents described.

Match analysis has been widely used for some time among football coaches world wide,[22 23]and more refined computer assisted methods based on video recordings have been developed.[24 25] A better understanding of the injury mechanisms and the events leading up to high risk situations is essential in order to design prevention programmes. Thus, the aim of this study was to develop and test a new video based

Table 1 Variables and categories used in the football incident analysis

Variables and categories	κ Inter	κ Intra
Ball possession *Attack*: a team is in possession, i.e. with ball control and necessary space and time for decision possibilities with the ball *Defence*: the opposing team is in possession, i.e. with ball control and necessary space and time for decision possibilities with the ball	0.85	1.00
Attack type *Set plays*: attacks that start by a set play and finish while players are still in original grouping (free kick, throw in, corner kick, goal kick, penalty kick, kick off, and drop) *Breakdowns*: attacks that start by winning the ball in play and maintaining and/or increasing imbalance in opponent defence throughout the attack *Long attacks*: attacks that start by winning the ball in play or a set play and progress without taking advantage of opponent's imbalance *Long attacks, including long pass*: long attacks with at least one pass that covers a minimum of one third of the playing field, i.e. about 35 m or more (includes goal kicks and clearance)	0.67	0.88
Positioning, i.e. a player's position in relation to the immediate opponent *One on one situation*: one against one (face to face, back to face, different sideways positions) *Not one on one situation*: without involving an opponent player or when one against two or more players	0.80	0.83
Team action before injury risk incident, i.e. type of passing actions by the attacking team before injury risk incident *Long pass*: long pass forwards (35 m or more), long pass from goalkeeper, long clearance, long pass across the field *Short pass*: short pass forwards, short pass backwards, wall pass, short pass from goalkeeper *Flick*: flick using either foot or head *Cross*: a pass from side corridor into the score box *Deflection*: unintentional pass from fellow or opponent player	0.74	0.93
Localisation on the field, i.e. zones on the playing field (fig 1) *Defensive third*: the defending third of the playing field *Midfield zone 1*: the first half of the middle third of the playing field *Midfield zone 2*: the second half of the middle third of the playing field *Attacking third*: the attacking third of the playing field *Score box*: prolongation of the penalty area to half line between 16 m line and the nearest midfield zone	0.84	0.84
Attack effectiveness *Effective attack*: attack that ends up with shooting attempt and shot off target, shot on target, or goal *Non-effective attack*: attack that ends up with none of the above	0.88	1.00
Ball winning situations *At the moment of ball winning*: attempting to regain possession (1st defender) *After ball winning (up to 5 s)*: immediately after regaining possession (1st attacker) *After 2nd ball*: regaining ball after deflection from opponent player (1st attacker) *Not ball winning situations*: attempting to maintain possession (1st attacker) and incidents away from the ball	0.84	0.94
Degree of balance in opponents' defence *Good balance*: Both numerical (i.e. equal or greater number of opponents on the right side of the ball) and positional balance (i.e. pressing, covering and marking defending tasks) are achieved *Average balance*: either numerical or positional balance is achieved *Poor balance*: neither numerical nor positional balance are achieved	0.63	0.88
Player role *1st defender*: pressing defending player on the right side of the ball *Other defender*: all the remaining players of the defending team *1st attacker*: player with the ball on the attacking team *Other attacker*: all the remaining players of the attacking team	0.77	0.97
Player position, i.e. static positions of players on the field based on playing formations (*Goalkeeper, fullback, central defender, wing midfielder, inside midfielder, central midfielder, striker*)	1.00	1.00
Type of individual action with the ball *Dribbling* (including moving with the ball), *heading, receiving the ball, screening tackling, turning, flicking* (using foot or head), *passing, goalkeeper action, shooting, blocking, clearing, ball to body accident, unclear action and no action with the ball*	0.80	0.89
Degree of individual ball control *High level of control*: in control of the ball after receiving it *Low level of control*: not in control of the ball	0.83	0.87
Player's movement direction i.e. movement direction in relation to the opponent's goal (*forward, sideward, backward, no movement*)	0.78	0.90
Player's movement intensity *High intensity*: including sprinting and moderate intensity running *Low intensity*: including jogging, walking and standing	0.81	0.82

Table 1 Variables and categories used in the football incident analysis

Variables and categories	κ	
	Inter	Intra
Duel type *In duel*: - Heading duel-active (heading actively) and heading duel-passive (unaware of heading duel or attention towards other action with the ball) - Tackling duel-active (tackling actively) and tackling duel-passive (unaware of tackling duel or attention towards other action with the ball) - Screening duel-active (screening actively) and screening duel-passive (unaware of screening duel or attention towards other action with the ball) - Running duel and *other* (pushing, kicking, obstruction, stepping, collision) *Not in duel*: without involving opponent player(s)	0.85	0.88
Attention *Attention towards primary duellist*: player concentrates on immediate opponent *Attention towards the ball*: player concentrates on the ball; - On the ground (ball in contact with the playing surface) - In the air (ball at head height and upwards) - Ball between head height and playing surface *Attention towards team mate* - Near (in the vicinity of the ball) - Further away (not in the vicinity of the ball)	0.96	0.96
Tackling type *Being tackled*: involving a player that is being tackled by the opponent (from front, from side, from back) *Not being tackled*: involving attacking player that is not being tackled *Tackling*: involving a player that is tackling the opponent (from front, from side, from back) *Not tackling*: involving defending player that is not tackling	0.79	0.88
Type of incident risk action *Against 1st attacker towards "back room"*: attempt to stop a player with the ball from penetrating a space behind the last defender (tackling, obstruction, holding) *Against 1st attacker elsewhere* *Against 1st defender* *Action away from the ball* *Actions against other players* (2nd and 3rd attackers and defenders)	0.80	0.94
Referee's decision *Free kick for* *Free kick against* *Yellow card* *Red card* *No foul called*	0.78	0.78

Results from interobserver and intraobserver analysis are shown in the right hand columns.

method for match analysis combining football specific and medical information.

METHODS

Videotapes from 35 of 76 (46%) official Norwegian under 21 matches played in the period February 1994 to June 1998 were traced. Of the 35 matches, 17 were official qualification matches for the Olympic Games, European or World Championships, and 18 were friendly matches. Of the 35 videotapes, 30 covered the match in full, whereas five tapes randomly covered 50–80 minutes. The total duration of the video recordings was 3017 minutes.

The videotapes were reviewed by two experienced doctors (TEA and LE), one of them (TEA) being the team doctor of the Norwegian under 21 team. All situations in which the match was interrupted by the referee, or a Norwegian player was on the ground for more than 15 seconds, or the player appeared to be in pain or received medical treatment were noted as an injury risk incident. These incidents, including the playing events leading up to each incident, were transferred to a master videotape.

Football incident analysis (FIA)

Two football coaches with long experience in match analysis reviewed and classified each of the incidents on the master videotape based on predetermined criteria developed during pilot testing, and their results were compared using κ analysis to determine interobserver reliability.[26] One of them reanalysed the tapes three months later to determine intraobserver reliability.

The methodology for match analysis, which is used by soccer coaches to evaluate patterns of play and team and player performance,[24] was modified for this study. FIA is a video based method allowing incidents to be described using 19 variables, each with two or more categories (table 1). FIA describes each incident related to: (*a*) the injured player—for example, playing position, action with the ball, movement direction, and intensity; (*b*) the injured team—for example, the type of relational skill including all types of passes; (*c*) the opposing team—for example, degree of defensive team balance; (*d*) match—for example, match type, match time, playing phase; (*e*) attacking play—for example, attack type, attacking effectiveness; (*f*) defensive play—for example, duel type, tackling type, ball winning; (*g*) playing field—for example, localisation and positioning in one on one situations; (*h*) foul play—for example, foul type, referee's decision.

The playing field was divided into zones and corridors (fig 1). The classification of playing positions was based on a 1:4:5:1 or 1:4:3:3 formation, whichever appropriate for the game in question.

Injury records

Information on injuries was obtained by retrospective review of team medical records by the team doctor (TEA). All

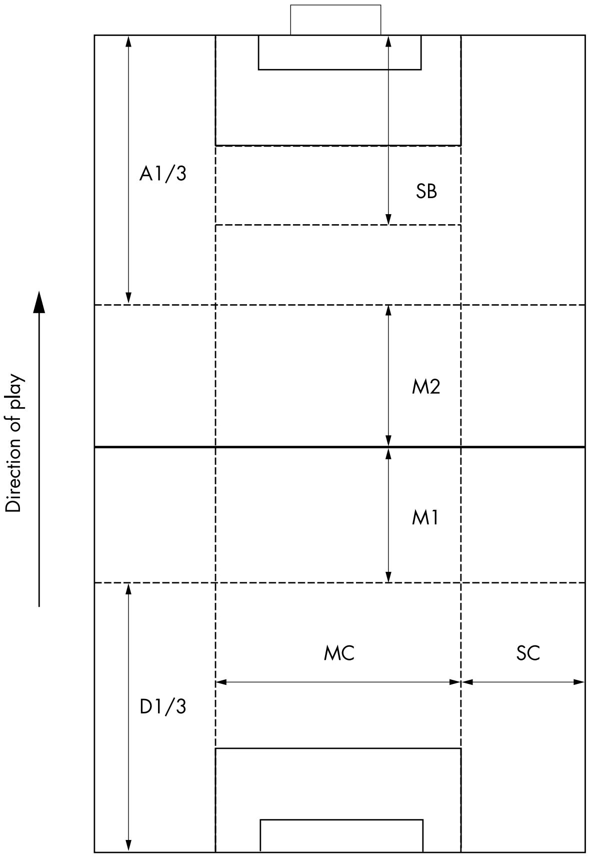

Figure 1 Zones of the playing field. The defensive zone is defined as the defending third of the field (D1/3), midfield 1 is the first half of the middle third (M1), and midfield 2 is the second half of the middle third (M2). The attacking zone is the attacking third (A1/3), and the score box is the zone between the prolongation of the short sides of the penalty area until the half way line between the 16 m line and the line dividing attacking and middle thirds (SB). The side corridor (SC) is one third of the width of the field on each side and the middle corridor is the middle third (MC).

traumatic injuries had been systematically recorded during training camps and matches since February 1994. Each incident identified on the videotapes was cross referenced with the medical records and classified as an injury if the player had been unable to participate in training or match play for at least one day after the incident. Injuries were classified as minor when the player could not practise soccer normally or play matches for one to seven days, moderate if absent for 8–21 days, and serious if absent for more than 21 days.[4] Injuries were classified as contusions, sprains, strains, fractures, or lacerations.

Statistical analysis

κ correlation coefficients were calculated for interobserver and intraobserver agreement.[26] Coefficients of 0.81–1.00 are generally interpreted as very good, 0.61–0.80 as good, 0.41–0.60 as moderate, 0.21–0.40 as fair, and less than 0.20 as poor.[26]

RESULTS

Incidents and injuries

During the 35 matches available for video analysis, 52 incidents were recorded for the Norwegian team—that is, 1.6 incidents per team per match or 94 incidents per 1000 player hours. Of the 52 incidents, 16 (31%) led to traumatic injuries—that is, 0.5 injuries per match or 29 injuries per 1000

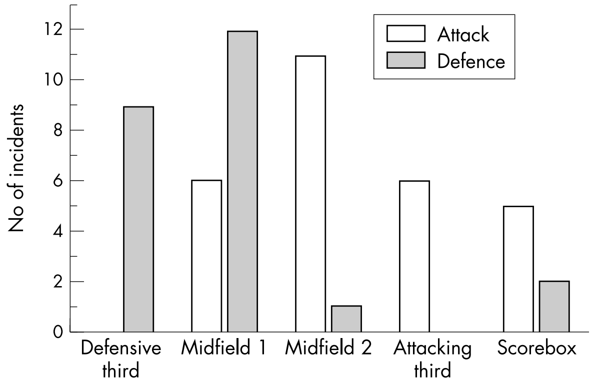

Figure 2 Number of incidents in the different zones of the field during the attacking or defending playing phases (n = 52).

player hours. Injuries and incidents were distributed evenly throughout the six 15 minute periods of the game (χ^2, p = 0.50).

Of the 16 injuries, seven were classified as serious, three as moderate, and six as minor. Most of the injuries affected the lower extremities: four ankle, three foot, three knee, one lower leg, and one thigh injury. In addition, there were three head and one wrist injury. Five of the 16 injuries were sprains, four contusions, four fractures, and three lacerations.

FIA results

The κ analysis showed that reliability was high and within acceptable limits for all the variables used. The inter-rater agreement was good (0.61–0.80) for 10 variables and very good (>0.81) for nine variables. The intrarater agreement was very good for 18 variables and good for one variable.

Of the 52 incidents recorded, 28 occurred when the team was in the attacking phase (eight injuries) and 24 in the defending phase (eight injuries). Most of the incidents during defence occurred in the defensive zone or midfield zone 1, whereas most of the incidents during offence took place in midfield zone 2 and the attacking zone (fig 2). Midfielders—that is, central midfielder, inside left/right midfielder, and wing midfielder—were exposed in 67% of the incidents. Most of the midfielder incidents occurred in breakdown attacks or during long attacks by the opponent (table 2).

Most of the offensive incidents occurred during breakdown attacks (table 2). Of the 17 incidents that occurred during breakdown attacks, only one took place within the first five seconds after gaining possession of the ball, and in nine cases the player involved had complete ball control. Of the 28 offensive incidents, only one was classified as an attack that ended up with a shooting attempt, a shooting attempt on goal, or a goal, whereas 27 attacks were classified as not effective—that is, with little potential to score a goal (fig 3). In 17 cases a short pass was the last team event before an offensive incident, whereas there were only five incidents after long forward passes. In 19 offensive incidents, the opponent was in good defensive balance at the time of the incident, whereas the opponent team balance was average in eight cases and poor in one (fig 4). The intensity of play was high in 21 of the offensive incidents.

Most defensive incidents occurred during long attacks by the opponent (table 2). Of the 17 incidents that occurred during opponent long attacks, 16 took place at the ball winning moment or within five seconds of the player winning possession of the ball. Of the 24 defensive incidents, two were classified as attacks with shooting attempts, three as attacks with shooting attempts at goal, and 16 as attacks without potential for scoring a goal (fig 3). In 17 cases a short pass was the last opponent team event before an incident, and there were three incidents after a long forward pass (fig 4).

Table 2 Number of incidents during the attacking and defending playing phases for goalkeeper, defenders (i.e. full backs and central defenders), midfielders (i.e. central, inside left/right, and wing midfielders), and striker during different attacking types (i.e. set plays, breakdown attacks, and long attacks) (n=52)

	Goalkeeper	Defenders	Midfielders	Striker	All players
When attacking					
Set play	0	0	4 (2)	0	4 (2)
Breakdown	0	1 (0)	14 (7)	2 (1)	17 (8)
Long attack	0	1 (0)	5 (1)	1 (1)	7 (2)
When defending					
Set play	0	1 (0)	2 (0)	1 (0)	4 (0)
Breakdown	0	2 (0)	1 (0)	0	3 (0)
Long attack	2 (1)	6 (0)	9 (3)	0	17 (4)
Total	2 (1)	11 (0)	35 (13)	4 (2)	52 (16)

The distributions of injuries are shown in parentheses (n=16).

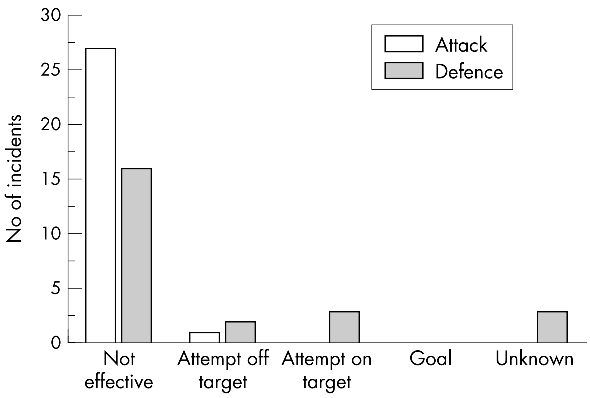

Figure 3 Number of incidents classified according to attack effectiveness—that is, whether the attack was not effective or had potential, that is, an attempt off target, attempt on target, or a goal was scored (n = 52).

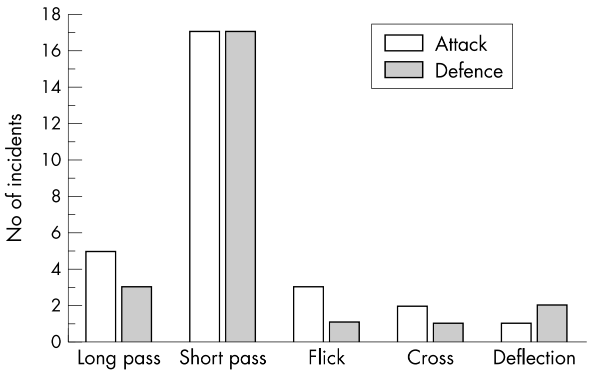

Figure 4 Number of incidents classified according to the final team event by the attacking team before the incident—that is, whether this was a long pass, short pass, flick, cross pass, or a deflection (n = 52).

Most incidents (70%) were the result of tackling duels (fig 5). Of the 21 offensive incidents resulting from tackling duels, in 19 cases the exposed player was unaware of the opposing player or engaged in another activity (passive duellist). In eight incidents the exposed player was tackled from the front, in seven from the side, and in four incidents from the rear. Of the 15 defensive incidents resulting from tackling duels, the exposed player was the active duellist in seven cases and the passive in eight cases. Of the seven active tackling duels, the

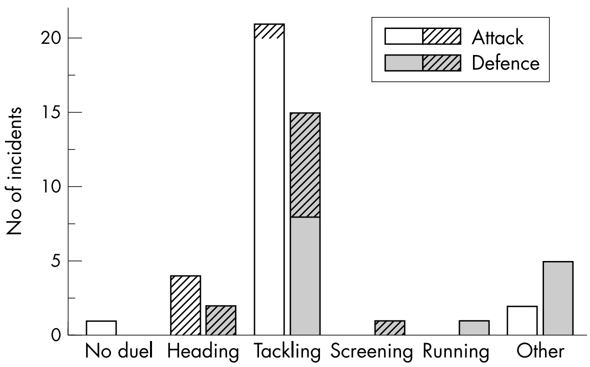

Figure 5 Number of incidents occurring in duels—that is, heading, running, tackling, screening, or other duels (table 1[1])—while in the attacking or defending playing phases. Passive duels are shown as hatched bars (n = 52).

exposed player was tackling from the front in five cases and from the side in two cases.

In 27 (52%) of the incidents, no free kick was awarded by the referee, 14 led to a free kick for the exposed player, and one led to a free kick against. Eight incidents resulted in a yellow card, whereas no red card was shown. In two incidents the decision of the referee was not known.

DISCUSSION

The main outcome of this study was that FIA has been developed as a reliable tool to analyse and describe video recordings of incidents and injuries in football specific terms. Although soccer is a complex game in which it is difficult to classify the various playing actions and player interactions, the interobserver and intraobserver reproducibility for most variables developed during pilot testing of FIA was high (table 1).

It should be noted that this study has some limitations, which must be taken into account when interpreting the results. It is a retrospective study, and the number of games and thus incidents and injuries are few. Therefore we have not presented data breakdowns for all variables and categories, because there would be very few cases in each category. Also, all the incidents included were taken from one team, the Norwegian under 21 team. The patterns observed may be a reflection of the playing style of this particular team. Care should be taken not to extrapolate these results to international under 21 football in general or other levels of play. In fact, one of the characteristics of the playing style of the Norwegian team is the focus on intensive and well balanced defensive play, combined with quick breakdown attacks whenever they gain possession of the ball. It is therefore not surprising that the incidents follow the same pattern. However, the main objective of this study was to develop FIA as a descriptive tool, and further studies are necessary with larger samples of incidents involving many teams, at both the international and national level.

Keeping these limitations in mind, the analysis of the 52 incidents included showed that they were evenly distributed between the attacking and defensive phases of the game. Most of the offensive incidents occurred during breakdown attacks—that is, attacks that start by winning the ball from the opponent and where the opponent defence is out of balance—usually in the midfield zones. Most of the defensive incidents occurred during long attacks in the defensive zone or midfield 1. Midfielders accounted for nearly 70% of the incidents, and 70% were the result of tackling duels—most with high intensity, where the exposed player was unaware of the opponent player tackling him. Few of the incidents were classified as attacks with goal scoring opportunities. In other words, although the study is small, these results challenge some of the myths surrounding the mechanisms of acute football injuries—for instance, that all player positions are at equal risk of injury and that incidents mainly occur as professional fouls in or near the score box to prevent a scoring opportunity or goal. Most authors have stated that the player position does not seem to influence the injury rate,[5] and in two other studies strikers[27] and defenders[21] have been seen to be most prone to injury. The present results suggest that most incidents result from the "war of the midfield area", where the aim is either to win the ball when the opponent is on the attack and unbalanced defensively, or to stop the opponent having won the ball from exploiting his tactical advantage.

The validity of using the definition of incident as we have—that is, match stopped because a player appeared to be injured or received medical attention—as the unit of analysis can also be questioned. It may be that in some cases players were simply simulating an injury to gain some tactical advantage. However, the fact that as many as one in three incidents resulted in a time loss injury suggests that the situations selected were associated with an appreciable risk of injury. This does not mean that our definition of incident gives a description of all situations taking place during a game with susceptibility of an injury. This is probably not the case. We have analysed several of the games, and found that there are 120–150 situations in each game where there is player to player contact. In addition, we know that some injuries occur without contact between players. However, it should be noted that we could not find any case of a contact injury in the medical records that was not identified through the video analysis. The quality of the TV production—for example, the number of cameras and camera angles used—is obviously also a factor that could prevent us from discovering all injuries or from providing a precise analysis of the events.

Few other studies have looked at injuries among international and professional football players, but the incidence, localisation, and type of injury found in our study correspond to findings in earlier studies.[21 27–30] The incidence of time loss injuries was high—nearly 30 injuries per 1000 player hours—compared with elite national levels in some studies,[4 5 31] but corresponds well with other studies of professional and elite players.[5 29 30] However, the definition of injury and interpretation of absence varies between studies and makes it difficult to compare results.[4 5 32] In agreement with numerous studies,[4 5 33] lower leg injuries such as ankle and knee sprains were the most common, but it appears that the ratio of more serious and moderate injuries to minor injuries may be higher than in lower divisions or adolescent football.[4 5]

It is essential to understand the causes of sports injuries before potentially effective preventive measures can be suggested. It is important to realise that causation in most cases is multifactorial: injuries are often the result of a combination of internal risk factors (player characteristics), external risk factors (such as environmental and equipment characteristics), and injury mechanisms.[6 34 35] Injury mechanisms have traditionally been described in purely biomechanical terms—that is, the kinematics and kinetics of the injured limb at the time of injury. In our opinion, the description of injury mechanisms must include an analysis of the events leading up to the injury situation to be comprehensive. FIA has been developed with this in mind—to assess complex interactions leading to situations with a high risk of injury. One finding that should be explored further in the context of injury prevention is that, in most of the tackling incidents, the player seemed not to be fully aware of the situation, but had his attention directed to another player, the field of play, or the ball. If this is shown to be the case in future larger scale studies, it may be possible to specifically train players to be more aware of the playing situation around them to avoid "surprise" tackles.

We do not propose that FIA should be used routinely to analyse all the games of a particular football club or national team, but that it should primarily be used as a research tool. However, FIA has been developed from an established method for match analysis. Coaches routinely use this method to analyse team and individual performance in games. In addition, a computerised system is available, the Mastercoach system, which merges digital video with statistical information on each incident. The advantage of the computerised system is that it speeds up the analysis—a trained observer needs only 90 minutes to analyse the performance of one team in one match. Another advantage is that the coach can use the system to train players to perform better in tactical video sessions. When larger databases of injuries and high risk incidents have been established, the system could also be adapted to enable coaches to train players to become aware of the characteristics of potential injury situations, such as specific tackling or heading situations. We are currently evaluating the effect of this approach to injury prevention in a cohort of football players.

The role of the referees and their interpretation of the rules during a match can also be assessed more effectively with FIA. Hawkins and Fuller[21 29] have shown that about one in four injuries result from foul play in professional football, a result that compares well with the present results. However, whether the rule interpretation of the referees was adequate in situations classified as non-fouls has not been examined.

Video analysis can also be a powerful tool in the analysis of the mechanics of specific injury types such as ankle, knee, and head injuries. The little information that we have at present on the mechanisms of these injury types is mainly from player interviews, a method limited by recall bias. Systematic collection of videotapes for biomechanical analysis of ankle, knee, and head injuries could result in a more precise understanding of the causes of injuries in football. Video analysis has been used by McIntosh *et al*[36] to describe the dynamics of concussive head impacts in rugby and Australian rules football.

Conclusion

This study shows that video analysis of incidents is a potentially valuable tool for understanding the events leading up to injuries in football.

ACKNOWLEDGEMENTS

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Take home message

It is difficult to describe and classify the various playing actions and player interactions in football. Therefore little is known about the playing situations leading up to injuries. Football incident analysis has been developed to describe incidents with a high risk of injury, and appears to be a valuable instrument that can help us to understand the mechanism of football injuries.

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Paper II

ORIGINAL ARTICLE

Video analysis of injuries and incidents in Norwegian professional football

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Objectives: This study describes the characteristics of injuries and high risk situations in the Norwegian professional football league during one competitive season using Football Incident Analysis (FIA), a video based method.

Methods: Videotapes and injury information were collected prospectively for 174 of 182 (96%) regular league matches during the 2000 season. Incidents where the match was interrupted due to an assumed injury were analysed using FIA to examine the characteristics of the playing situation causing the incident. Club medical staff prospectively recorded all acute injuries on a specific injury questionnaire. Each incident identified on the videotapes was cross referenced with the injury report.

Results: During the 174 matches, 425 incidents were recorded and 121 acute injuries were reported. Of these 121 injuries, 52 (43%) were identified on video including all head injuries, 58% of knee injuries, 56% of ankle injuries, and 29% of thigh injuries. Strikers were more susceptible to injury than other players and although most of the incidents and injuries resulted from duels, no single classic injury situation typical for football injuries or incidents could be recognised. However, in most cases the exposed player seemed to be unaware of the opponent challenging him for ball possession.

Conclusions: This study shows that in spite of a thorough video analysis less than half of the injuries are identified on video. It is difficult to identify typical patterns in the playing events leading to incidents and injuries, but players seemed to be unaware of the opponent challenging them for ball possession.

Football is a complex contact sport with high physical, technical, tactical, and physiological demands at the elite level,[1 2] and the risk of injury is considerable. Although differences in study design and injury definitions make a direct comparison between studies difficult, the incidence of injuries among adult male players has been estimated to be between 10 and 35 per 1000 game hours.[3 4]

While a considerable number of studies have described the incidence and injury pattern (injury type, localisation, and severity) in football,[3 4] much less is known about risk factors[3 5–8] or injury mechanisms.[9–15] The majority of the injuries are thought to be unintentional, resulting from chance or an error by the player injured or another player.[16] Hence, it is not surprising that only seven studies that have developed and tested injury prevention programs in football have been published to date.[15 17–22] Although these studies show promising effects of various generic interventions, prevention programs specific to the sport of football have not yet been developed. More sport-specific information is necessary to develop preventive measures targeting the injury mechanisms involved in football.

Based on player interviews, contact injuries have been found to represent 40–74% of all acute injuries,[9–11 23] mainly resulting from tackling duels.[9–11 23] Thus, receiving or making a tackle is thought to involve a substantial injury risk. Contact injury resulting in head injuries has received little attention in the literature.[24] The most common injury mechanism among elite football players is believed to be head-to-head contact, followed by head-to-ground and head-to-other body parts, for example, foot, knee, or elbow, or being hit in the head by the ball from close range.[14 25] Non-contact injury mechanisms are thought to account for about half of all acute injuries, with sprinting, shooting, or kicking being the most frequent causes reported.[9 11 23] However, in most studies the information on injury mechanisms has been collected retrospectively from either the player involved[9–15 23 26] or the team physician.[27] This approach is difficult due to recall bias by either the team physician or the injured player, and since injuries happen quickly, often in complex situations, the description may be incorrect.

Most elite football matches are televised, so using video recordings instead of post-injury player interviews can improve our ability to more objectively identify and understand the injury mechanisms. However, since football is a complex game, it is not easily described in quantitative terms, whether attempting to analyse the flow of the game, player-to-player interactions, or goal scoring opportunities, or to describe injury situations. Nevertheless, video analysis represents an opportunity to analyse and describe the events typically leading up to an injury situation in football-specific terms. Hawkins and Fuller[28] analysed video recordings from 44 of 52 matches in the 1994 World Championship and 181 matches at three levels of professional football in England. They found that between 15% and 29% of incidents resulted from foul play. However, their analysis was limited to the effect of foul play on injury risk, and they had limited access to medical information from the incidents described. Furthermore, Rahnama *et al*[29] assessed the exposure of players to playing actions during English Premier League matches and found that more than one third of the playing actions were judged to have some level of injury potential (assessed subjectively on the likelihood of the actions to produce an injury). Unfortunately, a more detailed description of the characteristics of high-risk playing actions was not provided.

Match analysis has been widely used for some time among football coaches worldwide,[30 31] and more refined computer-assisted methods based on video recordings have recently been developed.[32 33] A better understanding of the injury mechanisms and the events leading up to high-risk situations

Abbreviations: FIA, Football Incident Analysis; RR, relative risk

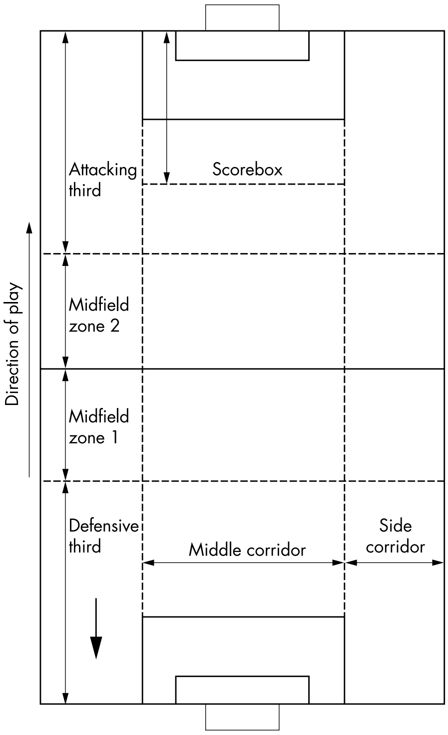

Figure 1 Zones of the playing field. The defensive zone is defined as the defending third of the field, midfield zone 1 is the first half of the middle third, and midfield zone 2 is the second half of the middle third. The attacking zone is the attacking third and the scorebox is the zone between the prolongation of the short sides of the penalty area until the half way line between the 16 m line and the line dividing the attacking and middle thirds. The side corridor is one third of the width of the field on each side of the middle corridor.

is essential in order to design future prevention programs. Football incident analysis (FIA)[34] is a video-based method that combines football-specific and medical information to describe how injuries and high-risk situations of injury occur. Thus, the purpose of this study was to describe the characteristics of injuries and high-risk situations in the Norwegian professional football league during one competitive season using FIA.

METHODS

Videotapes and injury information were collected prospectively for the regular league matches during the 2000 Norwegian season (April through October). The regular league is a double round robin competition with home and away matches between 14 teams, resulting in a total of 182 matches.

The Norwegian Broadcasting Cooperation (NRK) and TV2 Norway secured a weekly delivery of DVC pro and Beta SP quality video cassettes from 174 of the 182 matches (96%). Regional TV-production teams with one to three cameras were responsible for most of the recordings; 20 matches were live broadcasts with six cameras, including two high-speed slow-motion cameras. Of the 174 videotapes, 157 covered the match in full, while the remaining 17 covered 73 min on average (range: 36–87 min). The total duration of the video recordings was 15 367 min, which corresponds to 256 h of football. The total playing time not covered by video tapes was 283 min which corresponds to 2% of the matches covered by this study.

The videotapes were reviewed by one physician (TEA) and one expert on football match analysis (AT). All situations where the match was interrupted by the referee, one or more players lay down on the pitch for more than 15 s, and the player(s) appeared to be in pain or received medical treatment, were noted as an incident. The 15 s was chosen because that was thought to be long enough to avoid situations where players intentionally lay down either to rest or to delay playing time. These incidents, including the entire play leading up to each of them, were transferred to a master videotape.

FIA

The incidents on the master videotape were analysed using FIA, a video-based method allowing incidents to be described using 19 variables, each with two or more categories, which have been described in detail in a previous report.[34] This analysis describes each incident related to the: (1) injured player (for example, playing position, action with the ball, movement direction and intensity); (2) injured team (for example, type of relational skill, including all types of passes); (3) opposing team (for example, degree of defensive team balance); (4) match (for example, match type, match time, playing phase); (5) attacking play (for example, attack type, attacking effectiveness); (6) defensive play (for example, duel type, tackling type, ball winning); (7) playing field (for example, location; fig 1); and (8) foul play (for example, foul type, referee's decision).

Injury records

Club medical staff, physiotherapists, and/or physicians for all 14 first league clubs prospectively recorded all acute injuries that occurred during regular league matches. An injury was recorded if the player was unable to participate in training or match play for at least 1 day following the incident.[35] Injuries were classified as minor when the player could not fully participate in training or matches for 1–7 days, moderate if absent for 8–21 days, and serious if absent for more than 21 days.[3]

All players (about 330) with an A-squad contract who participated in matches were covered by the injury registration. A specific injury questionnaire was used and reports were collected on a monthly basis.

The form included information on the date of injury and during which match the injury occurred, as well as the time of injury. Furthermore, the playing position and the injury location were registered and injuries were classified as

Table 1 Number of injuries classified according to body location in males playing 174 Norwegian professional football matches during the 2000 season

	Injuries identified on video	Injuries not identified on video	Total
Head	9	0	9
Cervical spine/neck	1	1	2
Shoulder incl. clavicle	0	1	1
Elbow	0	1	1
Trunk	1	1	2
Abdomen	0	1	1
Thoracic/lumbar spine	2	4	6
Groin	0	7	7
Hip	1	1	2
Thigh	9	22	31
Knee	11	8	19
Lower leg	6	9	15
Ankle	10	8	18
Foot/toes	2	5	7
Total	52	69	121

The columns show the injuries identified on video (n = 52), injuries not identified on video (n = 69), and the total number of injuries (n = 121).

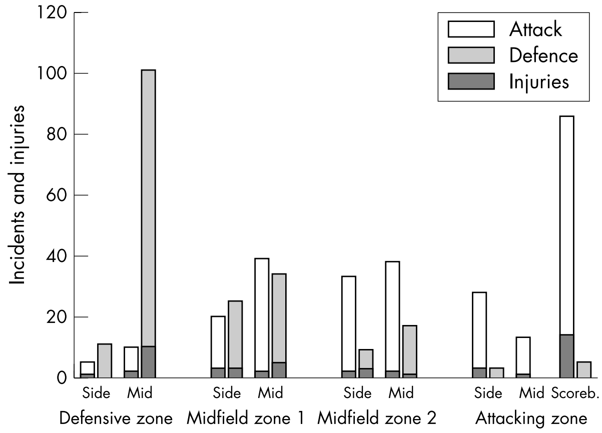

Figure 2 Number of incidents (n = 425) and injuries (n = 52) in the different zones of the field during the attacking and defending playing phases. Scoreb., scorebox.

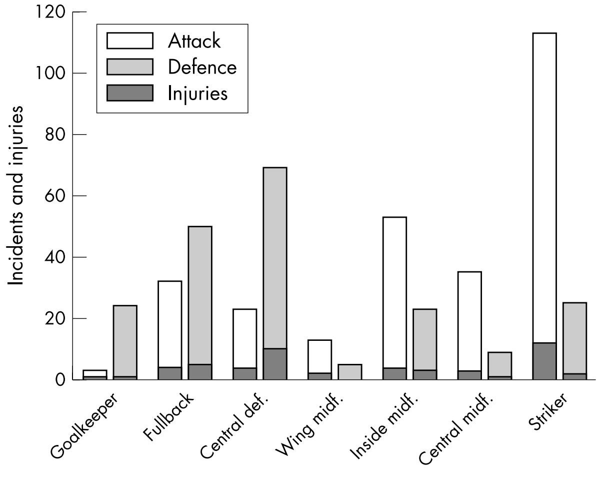

Figure 3 Number of incidents (n = 425) and injuries (n = 52) classified according to player position, that is, the static positions of players on the field based on playing formations. def., defender; midf., midfielder.

contusions, sprains, strains, fractures, or lacerations. Finally, each injury received a specific diagnosis using Orchard codes.[36]

Each incident identified on the videotapes was cross-referenced with the injury reports. In addition, the original tapes were re-examined to find incidents which had not been identified in the first video review. Although the injury reports included information on which match and what time during the match each injury occurred, we were only able to identify an additional four injuries during the second video review. However, these four did not fit with the definition of an incident.

Statistical analysis

Injury and incident rates were recorded as the number per 1000 player hours. The relative risk (RR) for injuries and incidents for specific playing positions was estimated as the ratio between incidents and injuries sustained to the number of players in the formation normally used by each team. Ten teams played a 4:3:3, three teams a 4:4:2, and one team a 4:1:2:1:2 formation. This means that the formation used to calculate RR consisted of one goalkeeper, two fullbacks, two central defenders, two wing midfielders, 1.3 central midfielders, 1.4 inside midfielders, and 1.3 strikers. Injury severity was compared between injuries observed on video and those not identified on video using chi-squared statistics. A chi-squared test with 5 df was used to test for equality of incidents and injuries between the six 15 min periods of the match.

RESULTS

Incidents and injuries

During the 174 matches available for video analysis, 425 incidents were recorded, that is, 1.2 incidents per team per match or 75.5 incidents per 1000 player hours. A total of 121 acute injuries were reported from the same matches, that is, 0.3 injuries per team per match or 21.5 injuries per 1000 player hours. Injuries and incidents were distributed evenly throughout the six 15 min periods of the matches (incidents: $\chi^2 = 5.4$; p>0.10; injuries: $\chi^2 = 2.1$; p>0.10, both NS).

Of the 121 acute injuries reported to have occurred during the matches by the club medical staff, 52 (43%) were identified on video. Of these, 18 (35%) were classified as serious, 16 (31%) as moderate, and 18 (35%) as minor injuries. Of the 69 injuries not identified on video, 14 (20%) were classified as serious, 20 (29%) as moderate, and 35 (51%) as minor (p = 0.18 *v* injuries identified on video, chi-squared test). Some 75% of the injuries affected the lower extremities. All the head injuries, 58% of the knee injuries, 56% of the ankle injuries, 29% of the thigh injuries, 40% of the lower leg injuries, and none of the groin injuries were identified on the videotapes (table 1). Of the nine head injuries, there were three concussions, three facial fractures, and three lacerations. Of the 22 thigh injuries not identified on video, 18 were muscle strains (table 1).

FIA

Of the 425 incidents recorded, 242 occurred when the teams were in the attacking phase (30 injuries) and 183 in the defending phase (22 injuries). A significant portion of the defensive incidents (91, 50%) and injuries (10, 45%) occurred in the mid-defensive zone, while many of the offensive incidents (72, 30%) and injuries (14, 47%) took place in the score-box (fig 2).

Strikers were exposed to 124 incidents (30%; RR = 2.5) and involved in 14 injuries (27%, RR = 2.3). The corresponding figures for central defenders were 78 incidents (18%; RR = 1.0) and 14 injuries (27%, RR = 1.5), fullbacks 73 incidents (17%; RR = 0.9) and nine injuries (17%, RR = 0.9), and inside midfielders 69 incidents (16%; RR = 1.3) and

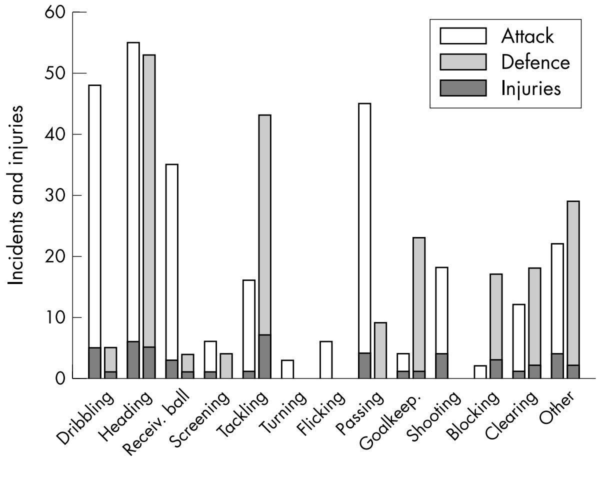

Figure 4 Number of incidents (n = 425) and injuries (n = 52) classified according to type of individual action with the ball. Goalkeep., goalkeeping; Receiv., receiving.

seven injuries (13%, RR = 1.1). Wing midfielders with 16 incidents (RR = 0.2) and two injuries (RR = 0.2) and goalkeepers with 25 incidents (RR = 0.6) and two injuries (RR = 0.4) were less prone to incidents and injuries (fig 3). Strikers and midfielders were more prone to incidents and injuries in the offensive playing phase, whereas defenders and goalkeepers were more susceptible when defending.

In the defending phase the most common categories of individual action with the ball that resulted in incidents were tackling (20%, injuries: 32%), heading (26%, injuries: 23%), blocking and clearance (16%, injuries: 23%), and goalkeeping (12%, injuries: 5%). In the offensive phase heading (20%, injuries: 20%), dribbling (18%, injuries: 17%), shooting (6%, injuries: 13%), and passing the ball (17%, injuries: 13%) caused most incidents and injuries (fig 4).

A short pass was the most common team event prior to incidents (49%) and injuries (48%), and this trend was the same for the defending and attacking playing phases (fig 5). Incidents and injuries after short passes were evenly distributed between the different playing positions, whereas strikers, central defenders, fullbacks, and goalkeepers were involved in more incidents after long forward passes compared to the other playing positions.

Of 242 offensive incidents (30 injuries), the level of ball control was low in 140 (17) cases, while the involved player had complete ball control in 102 (13) cases. Of the 183 defensive incidents (22 injuries), the level of ball control was low in 165 (21) cases, whereas the involved player had complete control of the ball in 18 (one) cases.

The opposing team was in good defensive balance at the time of the incident in 183 of the offensive incidents (17 injuries), while the opponent team balance was moderate in 45 cases (nine injuries) and poor in 14 cases (four injuries). The intensity of play was high in 175 of the offensive incidents (23 injuries) and low in 67 cases (seven injuries). Of the defensive incidents the intensity was high in 109 (14 injuries) and low in 74 cases (eight injuries).

Most incidents and injuries resulted from duels, primarily tackling duels with 194 incidents (46%) and 25 injuries (48%; fig 6A). Heading duels resulted in 91 incidents (21%) and eight injuries (15%). Being tackled from the side was the main cause of tackling incidents (20%) and injuries (23%; fig 6B). Player to player contact occurred in 90% of the 52 injuries observed on video.

Of the 242 offensive incidents (30 injuries), the exposed player appeared to be unaware of the opposing player in 238 cases (30 injuries). In other words, in only four (2%) of the incidents and none of the injuries was the attention of the exposed player directed towards his primary duellist (fig 7).

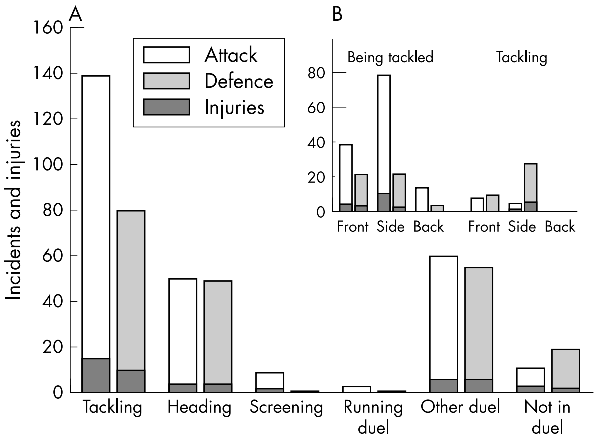

Figure 6 (A) Number of incidents (n = 425) and injuries (n = 52) classified according to type of duel. (B) Number of incidents (n = 425) and injuries (n = 52) classified according to type of tackling.

DISCUSSION

The aim of the present study was to describe the events leading to football injuries and incidents in the Norwegian professional league during one competitive season using a new video-based method, FIA.[34] An unexpected finding was that, although we performed a thorough review of the tapes, we were able to identify less than half of the acute injuries reported to have occurred during the same matches by the club medical staff. Secondly, although the majority of the incidents were tackling and heading duels it was difficult to detect any obvious patterns in the playing actions leading to incidents and injuries. Nevertheless, some common trends were discernible: (1) strikers appeared to be at greater risk than other players, (2) most incidents took place in the mid-defensive zone and in the scorebox in the attacking zone, and (3) in almost all cases the attention of the exposed player was not directed at the opponent causing the incident.

We were somewhat surprised to see that less than half of the injuries reported by the club medical staff to have led to subsequent absence from training or competition were identified on the videos. Of the three most common injury types—thigh, ankle, and knee—only 58% of the knee injuries, 56% of the ankle injuries, 29% of the thigh injuries,

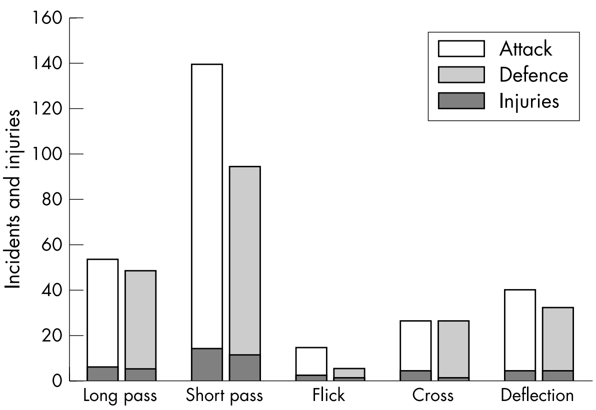

Figure 5 Number of incidents (n = 425) and injuries (n = 52) classified according to last team action, that is, type of passing actions by the attacking team prior to incident or injury.

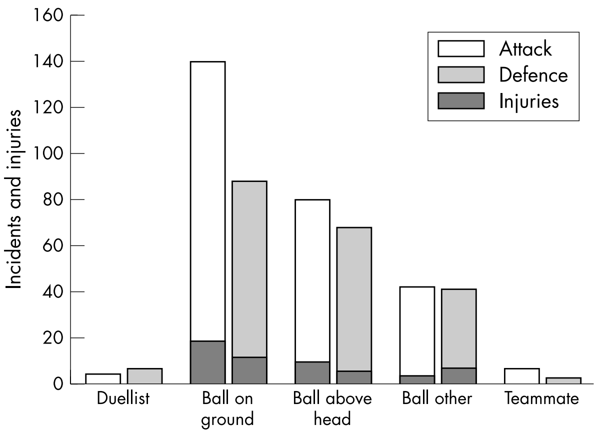

Figure 7 Number of incidents (n = 425) and injuries (n = 52) classified according to where the attention of the player appeared to be directed.

and none of the groin injuries were identified on video. Of the 22 thigh injuries not identified on the video, 18 were hamstring strains. This means that the majority of the hamstrings strains and a significant proportion of the knee and ankle injuries were not recognised as an incident, that is, there was no stoppage in play and the player did not go down on the pitch. The player was able to continue, and was not given treatment until halftime and was then substituted or was not treated until after the match.

These results imply that a video analysis alone, as previously used in the studies of Hawkins and Fuller[28 37] and Rahnama *et al*,[29] without simultaneous access to medical information from team medical staff may result in a biased description of how football injuries occur. Such an approach can be expected to reveal the more spectacular incidents resulting from player-to-player contact, but may overlook a significant number of injuries, in particular muscle strains to the thigh, groin, and lower leg, but also a number of ankle and knee sprains. In contrast, all of the head injuries were identified. Although severity was similar between injuries identified on video and those not identified, an analysis based on video tapes alone could be biased towards certain injury types or injury mechanisms, for example, contact injuries resulting from duels. Other injury types, for example, hamstrings strains, would be gravely underestimated, since only one-third were identified on the video tapes in the present study.

From a prevention point of view, it is disappointing that, in spite of a thorough classification of more than 400 incidents (and 52 injuries), it was not possible to identify any characteristic situations that could account for a significant proportion of the injuries in football, as has been done for ankle injuries in volley ball[38] and ACL injuries in skiing[39] and female team handball.[40 41] This is perhaps not surprising, since football is a complex sport with few fixed plays, few specialised skills, and countless potential player-to-player interactions. Rahnama *et al*, using a slightly different approach to ours, assessed the exposure of players to injury risk during ten English Premier League matches and found that a very large number of situations during football matches have some injury potential.[29] However, it should be noted that the approach used in both their and the present study was to look for patterns in the playing situations leading to incidents, since such patterns could potentially be used to develop preventive strategies. We have not examined the mechanisms of injuries in conventional biomechanical terms, nor were we able to look at specific injury types, for example, hamstring, knee, and ankle injuries, since the number of videos available for each of these was limited. Thus, we can not rule out that specific injury mechanisms may be involved for each of these types of injury. Although this was beyond the scope of the present study, a systematic analysis of the mechanisms causing these injury types might reveal patterns that could be used in injury prevention.

However, although no typical injury situations could be recognised, we observed some trends among the incidents and injuries identified on video. One was that strikers appeared to be at greater risk than others, another that more incidents took place in the mid-defensive zone and the scorebox. The literature on player function and injury risk is contradictory, with an early study supporting our finding that strikers are most likely to sustain an injury,[42] while most previous studies have concluded that player position does not seem to influence the injury rate.[4] Two recent studies have suggested that defenders[28] and midfield players[34] were the field positions with the greatest risk of injury. The apparent discrepancy between studies could reflect different playing styles between countries and different levels of play. However, it seems clear that it is not sufficient to focus on one or a few player categories to effectively prevent injuries in football.

Another trend was that, of the incidents and injuries identified on the videos, 90% resulted from player-to-player contact in duels, half of them from tackling duels (mainly from the side) and 15% from heading duels (fig 6). These results correspond both with the observations of Rahnama *et al*,[29] who found that all major injuries (that is, where the player received treatment and left the field for the remainder of the game) occurred from receiving a tackle, and with the questionnaire study in Finnish elite football by Lüthje *et al.*[10] However, it is important to keep in mind that more than half of our injuries were not identified on the video tapes. A similar bias can be expected in the study by Rahnama *et al*,[29] and their conclusion that the majority of injuries were linked to contesting possession may for that reason be flawed. Although the mechanisms for injuries not seen on tape are unknown, it appears less likely that they resulted from duels, since they did not result in a player going down on the pitch. As mentioned above, video analysis is likely to overestimate the percentage of acute injuries resulting from duels, unless medical information is available from the same matches. This suggestion is corroborated by other studies based on player and medical staff reports, showing that about half of all acute injuries were contact injuries.[12 23]

Perhaps the most promising finding from a prevention point of view was the analysis of where the attention of the injured player appeared to be focused. It must be acknowledged that evaluating player attention based on the video pictures can be difficult in some cases. However, based on our subjective judgement the attention of the injured player was directed towards his primary duellist in only 2% of the cases. It appears that in most cases the players were fully concentrated on the ball and did not have the overview that may be necessary to evade an opponent contesting possession and avoid injury. It may be hypothesised that injuries can be prevented by getting coaches and players to focus on this aspect during training to try to increase their functional field of vision and be more conscious of the actions of opponents and team mates.

Improved ball-handling skills would also reduce the need to focus on the ball at all times during play. On the basis of the findings in this study, the coaches may be advised to focus on technical skills for different playing positions, especially the first touch. Furthermore, they should focus on improving the players' functional field of vision and awareness of opponents and team-mates in their immediate vicinity.

Along the same lines, it may be possible to prevent injuries by raising the awareness of potential injury situations among players. Computer-based tools for match analysis are widely used by coaches, and they provide important information on each player's movements and ball involvements during a match.[32 33] Video sessions are routinely used, at least in professional teams, to improve player and team performance. A similar approach could be tested to avoid injury. A player and the coach and/or a member of the medical staff could review video-recordings of duels and other actions by the player to identify situations during a match with a potential for injury and develop strategies to minimise risk.

CONCLUSIONS

This study shows that less than half of the acute time-loss injuries that were reported by club medical staff to have occurred during football matches were identified through a thorough review of video tapes from the same matches. Furthermore, the majority of the injury risk incidents occurred during tackling and heading duels. Although an extensive video analysis did not reveal one typical injury

What is already known

In football the risk of injury is considerable. Although a large number of studies have described the incidence and injury pattern (injury type, localisation, and severity), very little is known about the injury mechanisms. The majority of the injuries are thought to be unintentional, mainly resulting from tackling duels.

What this study adds

Less than half of the injuries that occurred during matches were identified through video analysis indicating that many football injuries result from non-contact mechanisms. No single specific playing situation was recognised as typical for football injuries. However, it may be possible to prevent injuries by teaching players improved awareness of opponents challenging them for ball possession.

situation or pattern characteristic of the events leading to incidents and injuries, some trends were observed. Strikers appeared to be at greater risk than others and more incidents took place in the mid-defensive zone or the scorebox. In almost all cases the attention of the player appeared to be focusing on the ball and directed away from the opponent challenging them for ball possession.

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Paper III

Rule Violations as a Cause of Injuries in Male Norwegian Professional Football

Are the Referees Doing Their Job?

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Background: Foul play is an important cause of injury in football. Reduction of foul play and adherence to the laws of the game may be possible interventions to reduce the rate of injuries.

Purpose: To evaluate how violations of the laws of the game contribute to injury and to investigate whether the decisions made by the referees are correct in high-risk situations.

Study Design: Prospective cohort study.

Methods: Videotapes and injury information were collected for 174 of 182 matches from the male Norwegian professional league during the 2000 season. Three Norwegian FIFA referees performed retrospective blinded evaluation of the 406 incidents.

Results: Less than one-third of the injuries identified on video and about 40% of the incidents with a high risk of injury resulted in a free kick being awarded. About 1 in 10 of these situations led to either a yellow or red card. The agreement between decisions made by the match referee and the expert referee panel was good, that is, their decisions agreed in 85% of the situations in which injury occurred.

Conclusions: There may be a need for an improvement of the laws of the game of football to protect players from dangerous play.

Keywords: football injuries; injury mechanisms; prevention; video recording

The speed, intensity, and aggressiveness of the game of football have increased over the past decades, especially at the professional level. The incidence of injury in modern top-level football matches is high,[12,13] and the overall risk of injury to professional players is about 1000 times higher than for industrial occupations.[12] Furthermore, Drawer and Fuller showed that the risk associated with acute injuries is unacceptable when evaluated against work-based criteria.[6] Football is a contact sport, and 42% to 74% of the acute injuries are considered a result of physical contact between players.[3,7,10,13,20,21,23] Previous studies have shown that tackling is the primary mechanism of nearly half of the anterior cruciate ligament (ACL) injuries[4] and most of the sprain injuries[3] in both the ankle and knee.[7,21]

Studies on prevention of football injuries are few,[5,9,14,18,24–26] and one explanation for the paucity might be the lack of solid evidence about the risk factors and mechanisms for football injuries at different levels of play. In several studies at lower levels, foul play has been proposed to be the most important cause of injury.[8,20,21,23] Hawkins and Fuller[10,11] showed that 15% to 29% of all injuries at the international and elite levels resulted from foul play, whereas the rest of the injuries occurred without a free kick being awarded by the referee. In all the nonfoul situations in which injury resulted, at least 60% still involved player-to-player contact, and it is not known whether referee performance was adequate in these cases. Since reduction of foul play and observance of the existing laws of the game have been proposed as possible interventions to reduce the rate of injuries,[8] it is important to assess how the laws of the game are being applied by the referees in injury situations.

Thus, the aims of this study were primarily to evaluate how violations of the laws of the game contribute to injury in football and, secondarily, to investigate whether the decisions made by the referees were correct according to the laws of the game of football in situations with a high risk of injury.

METHODS

Videotapes and injury information were collected prospectively for the regular league matches during the 2000

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Norwegian professional football league (April through October). The regular league is a double round robin competition with home and away matches between 14 teams, resulting in a total of 182 matches.

The Norwegian Broadcasting Corporation and TV2 Norway secured a weekly delivery of DVC pro and Beta SP quality videocassettes from 174 of the 182 matches (96%). Regional production teams with one to three cameras were responsible for most of the recordings, although 20 matches were live broadcasts with six cameras, including two high-speed, slow-motion cameras. Of the 174 videotapes, 157 covered the match in full, whereas for 17 matches the tapes covered 73 minutes on average (range, 36 to 87 minutes). Thus, the total duration of the video recordings was 15,367 minutes (256 hours).

The videotapes were reviewed by one physician (TEA) and one expert on football match analysis (AT). All situations in which the match was interrupted by the referee, one or more players laid down on the pitch for more than 15 seconds, and the player(s) appeared to be in pain or received medical treatment were noted as an incident. This resulted in a total of 406 incidents that were transferred to a master videotape, including the play leading up to each of them. In 19 of the 406 incidents, two players went down on the pitch.

Football Incident Analysis (FIA)

The incidents on the master videotape were analyzed using FIA by one of the authors (AT).[2] FIA is a video-based method allowing the playing events leading to incidents to be described using 19 variables such as related to playing position, action with the ball, movement direction and intensity, type of passes, attack type, tackling type, and foul play. The complete FIA results are reported separately.[2] The decision made by the referee for each incident was recorded from the video as no foul or a free kick for or against the exposed player, and whether the situation led to a yellow or a red card was also noted. Furthermore, ball possession was examined, and the exposed player was classified as being on the attack if his team had ball control and the necessary space and time for decisions with the ball, whereas the incident was classified as defensive if the opposing team was in possession of the ball. A *duel* was defined as an incident involving an opponent and was classified as heading, tackling, screening, running, or other (pushing, kicking, obstructing, stepping, or colliding). Heading, tackling, and screening duels were categorized into active and passive duels. *Passive duels* were defined as incidents in which the exposed player was challenged for ball possession by an opponent, whereas *active duels* were when the involved player was actively contesting ball possession. Tackling type was subdivided into *being tackled* (when the involved player was tackled by the opponent from the front, side, or behind) and *tackling* (when the involved player was tackling the opponent from the front, side, or behind).

Referee Expert Panel

Three Norwegian Fédération Internationale de Football Association (FIFA) referees with long experience in international football at the club and national team levels independently performed a retrospective blinded evaluation of the 406 incidents based on the master videotape. Blinding was accomplished by editing the video so that the decision of the match referee could not be seen. Their decisions were compared, and in 366 of the 406 incidents a majority agreement could be reached; that is, at least two of three in the referee panel agreed. The performance of the match referee was assessed by comparing his decision with the referee panel decision for these 366 incidents.

Injury Registration

Club medical staff, physiotherapists, and/or physicians, for all of the 14 first league clubs, prospectively recorded all acute injuries that occurred during regular league matches. An injury was recorded if the player was unable to participate in training or match play for at least 1 day following the incident.[3,19]

All players (approximately 330) with an A-squad contract who participated in matches were covered by the injury registration. A specific injury questionnaire was used, and reports were collected on a monthly basis. The form included information on the date of the injury, in which match the injury occurred, and the approximate time during the match the injury occurred. Furthermore, the playing position and the injury location were registered, and injuries were classified as contusions, sprains, strains, fractures, or lacerations. Finally, each injury received a specific diagnosis using Orchard codes,[22] and injury severity was classified according to the duration of absence. Injuries were classified as minor when the player could not fully participate in training or matches for 1 to 7 days, moderate if absent for 8 to 21 days, and serious if absent for more than 21 days. Detailed results from the injury registration are presented in a separate report by Andersen et al. (unpublished data, 2003).

Statistics

All analyses were performed using Statistical Package for the Social Sciences (SPSS). Kappa correlation coefficients were calculated to assess agreement between the decisions made by the match referee and the referee panel. Kappa values between 0.81 and 1.00 are generally interpreted as very good, 0.61 to 0.80 as good, 0.41 to 0.60 as moderate, 0.21 to 0.40 as fair, and less than 0.20 as poor.[1]

RESULTS

Incidents and Injuries

During the 174 matches available for video analysis, 406 incidents were recorded and analyzed regarding the decision made by the referee. Of these, 52 incidents resulted in injuries. In the 18 cases that led to minor injuries, no foul was called in 13, a free kick for in 4 (one yellow card), and a free kick against in 1 case. In the 16 cases that led to moderate injuries, no foul was called in 9 and a free kick for in 7 cases (four yellow cards, one red card). Of the 17 cases that led to a severe injury, no foul was called in 14, a free kick for in 3, and a free kick against in 1 (no yellow or red card). In 234 (58%) of the incidents, no foul was called by the referee, whereas 155 incidents (38%) led to a free kick for and 11 (3%) led to a free kick against the exposed player. In addition, 54 of the incidents that led to a free kick, all of them for the exposed player, also resulted in a yellow card (13% of the total number of incidents) and 2 in red cards (1%). In 6 of the incidents, the decision made by the referee could not be evaluated (2%). Of the 52 injuries seen on video, in 36 cases (69%) no foul was called, whereas 14 (27%) of the injury situations resulted in a free kick for and 2 (4%) in a free kick against the injured player. Five of the injury situations that led to a free kick also resulted in a yellow card (10% of the injury situations) and 1 in a red card (2%) (Fig. 1).

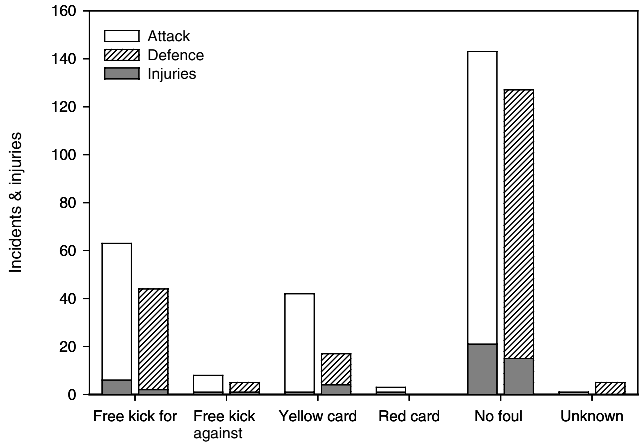

Figure 1. Number of incidents (n = 425) and injuries (n = 52) classified according to the playing phases and the referee's decision.

Match Referee Decision for Duels

Of the 406 incidents, nearly all (n = 381) resulted from duels, mainly tackling duels (n = 191) and heading duels (n = 82). Of the 82 incidents (eight injuries) that resulted from heading duels, the exposed player was actively heading in all but 5. In 65% of the heading incidents (four injuries), no foul was called, whereas in 28% of the cases (three injuries), a free kick for and in 6% (one injury) a free kick against the exposed player was called (Table 1). In the heading duels that led to a free kick, a yellow card was also awarded in 1 case but none of the injury situations.

A total of 191 incidents (25 injuries) resulted from tackling duels, and of these 151 (79%) were passive duels in which the exposed player was being tackled (76% injuries) and 40 (21%) were active duels in which he was tackling (24% injuries). In 32% of the 151 passive tackling incidents (58% injuries), the referee called no foul, whereas a free kick was called in 68% of the cases (42% injuries) for the involved player (Table 2). Of the passive tackling incidents, a yellow card was also awarded in 30% of the cases (21% injuries) and a red card in 1 case.

Expert Referee Panel

In 290 of the 366 incidents (39 of the 46 injuries), there was agreement between the match referee and the majority decision of the expert panel, that is, the cases where two out of three referees agreed (kappa = 0.65). There was no indication that the rule interpretation of the match referee was stricter or more lenient than the referee panel was (Table 3). The expert panel decided on a free kick for the exposed player in 33 incidents (2 injuries) in which the match referee called no foul. However, the match referee awarded a yellow card in 22 incidents (1 injury) in which the expert panel did not.

When examining the tackling duels only, in 128 of 173 incidents (17 of the 21 injuries) there was agreement between the match referee and the expert panel (kappa = 0.60). The match referee awarded a yellow card in 16 incidents (1 injury) in which the expert panel only gave a free kick for the exposed player. On the other hand, the expert panel awarded a free kick for the involved player in 15 inci-

TABLE 1
The Decision Made by the Match Referee for the Incidents (N = 406) and Injuries (n = 52) Related to the Types of Duels[a]

	No foul	Free kick for	Free kick against	Unknown	Total	Yellow card[b]	Red card[b]
Heading duel	53 (4)	23 (3)	5 (1)	1 (—)	82 (8)	2 (—)	—
Tackling duel	78 (16)	106 (8)	5 (1)	2 (—)	191 (25)	47 (4)	1 (—)
Screening duels	7 (2)	1 (—)	—	—	8 (2)	1 (—)	—
Running duel	3 (—)	1 (—)	—	—	4 (—)	1	—
Other duel[c]	69 (9)	24 (3)	1 (—)	2 (—)	96 (12)	3 (1)	1 (1)
Not in duel	24 (5)	—	—	1 (—)	25 (5)	—	—
Total	234 (36)	155 (14)	11 (2)	6 (—)	406 (52)	54 (5)	2 (1)

[a] The figures for injuries are shown in parentheses.
[b] All of the yellow and red cards also resulted in free kicks for the exposed player.
[c] Other duels: pushing, kicking, obstructing, stepping, and colliding.

TABLE 2
The Decision Made by the Match Referee for the Incidents (n = 191) and Injuries (n = 25) Resulting From Active or Passive Tackling Duels[a]

	No foul	Free kick for	Free kick against	Unknown	Total	Yellow card[b]	Red card[b]
Passive tackling duels							
From the front	14 (3)	36 (4)	—	—	50 (7)	17 (2)	—
From the side	33 (8)	53 (4)	—	—	86 (12)	23 (2)	—
From behind	1 (—)	14 (—)	—	—	15 (—)	6 (—)	1 (—)
Active tackling duels							
From the front	9 (—)	2 (—)	3 (—)	2 (—)	16 (—)	—	—
From the side	21 (5)	1 (—)	2 (1)	—	24 (6)	1 (—)	—
From behind	—	—	—	—	—	—	—
Total	78 (16)	106 (8)	5 (1)	2 (—)	191 (25)	47 (4)	1 (—)

[a] The figures for injuries are shown in parentheses. An *active* tackling duel is when the exposed player was being tackled; a *passive* tackling duel is when the player was tackling.
[b] All of the yellow and red cards also resulted in free kicks for the exposed player.

TABLE 3
The Decision Made by the Match Referee Versus the Majority Decision Made by the Expert Referee Panel (incidents where two of three referees agreed) for 366 Incidents (including 46 injuries) Observed on Video[a]

	Match referee decision				
Referee panel decision	No foul	Free kick	Free kick against	Yellow card	Red card
No foul	179 (32)	7 (2)	1 (—)	2 (—)	—
Free kick for	33 (2)	80 (5)	3 (1)	20 (1)	—
Free kick against	1 (—)	—	3 (—)	—	—
Yellow card	2 (—)	7 (1)	—	27 (2)	—
Red card	—	—	—	—	1 (—)

[a] In 40 cases (including 6 injuries), no majority decision could be reached by the referee panel. The figures for injuries are shown in parentheses. The expert panel deemed 20 incidents (1 injury) to be a yellow card in incidents in which the match referee only awarded a free kick. A free kick was given in 33 incidents (2 injuries) and a yellow card in 2 incidents in which the match referee called no foul.

In 59 of 73 heading duels (four of seven injuries), there was agreement between the match referee and the expert panel (kappa = 0.62). The expert panel deemed 7 incidents to be a free kick for the exposed player when the match referee called no foul, whereas the match referee awarded a yellow card in 1 incident for which the expert panel only deemed it a free kick.

DISCUSSION

One main finding of this study was that less than one-third of the injuries identified on video and about 40% of the incidents with a high risk of injury resulted in a free kick being awarded by the referee. Furthermore, about 1 in 10 of the situations led to either a yellow or a red card. The second main finding was that the agreement between decisions made by the match referee and the expert referee panel was good; that is, their decisions agreed in 85% of the situations in which injury occurred.

Methodological Considerations

When interpreting the findings of the present study, there are some methodological issues that need to be addressed. First, although we have used the judgment of the members of the expert panel as the gold standard to assess match referee performance, we cannot be sure that their decisions were correct. In most cases, they had only one camera view available, and the view angle of the match referee may have been different from the members of the referee panel in many of the situations. This means that the referee panel may have observed rule violations that the match referee was unable to see and vice versa. However, in contrast to the match referee, they had access to as many slow-motion replays as they needed, and this suggests that their decisions may have been correct in most cases. They were also chosen because of their background as FIFA referees with long international experience from the club and national team levels, and they are all at present referees. All the recordings were edited to blind the panel to the decision made by the match referee, but since the panel members were performing referees, they did lead some of the matches during the 2000 season. Thus, they may have been able to recognize some of the incidents. The referee panel reviewed the incidents independently, and 15% of the incidents had to be excluded from the analysis, in most cases because the recording of the situation was poor from a referee perspective and could not be evaluated by two of the referees.

It should also be noted that the style of football and the tradition of referring and adherence to the existing rules may differ between Norwegian football and other countries or international tournaments. Therefore, the results from this study on Norwegian professional football may not necessarily be generalized to other levels of play or female football.

Foul Play

The results of this study show slightly more rule violations compared with findings by Hawkins and Fuller from the 1994 World Cup finals, English professional league matches,[10] and the1996 European championship.[11] Studies at lower levels of adult and youth football also found slightly less foul play decisions in situations in which injury occurred.[15,17]

Nearly all injuries (90%) and incidents (94%) occurred in duels and resulted from player-to-player contact. Half of them were tackling duels, and in two-thirds of the tackling duels the injured player was being tackled, most often from the side. In about 60% of these injuries, no foul was called by the referee (see Tables 1 and 2). The most common mechanism of injury in football is direct contact between opponent players,[15] and in previous studies based on player or coach reports, 44% to 74% of the injuries are considered to be the result of physical contact between players.[3,7,20,21]

Studies based on video analysis have found similar results,[11,12] and in nonfoul incidents from which injury resulted, more than 60% resulted from player-to-player contact.[11] Hawkins and Fuller[11] found that the main mechanisms leading to these player-to-player contact injuries among professional football players were being tackled, tackling, and heading. Furthermore, the same authors highlighted the high numbers of injuries arising from player-to-player contact in nonfoul situations.[10,11]

Tackling and running were found to be the main mechanisms of injury among low-level adult and youth players in a Danish study.[21] The figures in this study correspond well with the findings in a recent study by Andersen et al. (unpublished data, 2000) and underline the importance of referees paying close attention to player-to-player contact situations during match play—in particular, tackling and heading duels.

Referee Performance

The correlation between the majority decision of the expert panel of referees and the match referee was good. In 89% of the 203 incidents for which a consensus decision was reached by the referee panel (three out of three), the agreement with the decision made by the match referee was very good[1] (kappa = 0.80, data not shown). To our knowledge, no previous study has assessed the performance of the match referee in injury-related situations in football. This study from the male Norwegian professional league shows that overall, the judgments of the match referees are according to the existing interpretation of the laws of the game and that there was no bias toward too strict or too lenient refereeing by the match referee.

Implications

Over the past years, attention has been directed toward fair play from both FIFA and the United European Football Association, and fair play is also part of the Champions League concept. Law 12 of the *Laws of the Game* describes how fouls and misconducts are penalized, as well as which offences are cautionable (yellow card) or should lead to being sent off (red card).[16] Nevertheless, injuries in football have long been linked to contesting ball possession, and FIFA has therefore looked at rules and rule enforcement by the referees to prevent dangerous play.

The present and other studies show that of the injuries and incidents with a potential for causing an injury from player-to-player contact, a foul is awarded by the referee in 15% to 40% of the cases.[3,7,10–12,20,21] Perhaps an assessment should be made, as previously suggested in two different studies,[8,11] to ascertain whether changes or improvements to the existing laws of the game could reduce the numbers of injuries in football. This focus on injury prevention is important and may help to reduce aggressive behavior from players, trainers, and spectators. However, the game of football is highly competitive, and at the top professional level, the glory and the financial benefits of winning are considerable. It may therefore be tempting for players to make use of all means—including aggressive tackling and intentional fouls—to be able to win the game. This development needs to be taken seriously, and the approach to require the referees to be stricter in their implementation of the existing laws of the game does not seem to be enough. The present study shows that compared with the referee panel, Norwegian football referees are not lenient in their interpretation of the rules.

In 34% of the incidents that led to either a free kick for or against the exposed player, a yellow (54 cases) or a red card (2 cases) was also given. However, it should be noted that during the 2000 competitive season in which this video analysis was performed, a total of 468 yellow and 24 red cards were awarded during the 182 regular league matches (personal communication, E. Reimert, Norwegian Football Association). This means that only about 10% of the yellow and red cards that were awarded during the season were given in high-risk injury situations detected during our video analysis. This indicates that player cautions and expulsions are primarily used for other rule violations than those associated with a high injury risk. This is perhaps not surprising since according to the *Laws of the Game*, a player should be cautioned and shown the yellow card for the following offences: unsporting behavior, showing dissent, persistently infringing the laws of the game, delaying the restart of play, failing to respect the required distance when starting play, and entering or leaving the field of play without permission.[16] This means that none of the seven offences that may lead to a yellow card is explicitly related to injury risk. The *Laws of the Game* also state that a player should be sent off and shown the red card for any of the following offences: serious foul play, violent conduct, spitting, deliberately handling the ball to deny a goal or goal-scoring opportunity, using abusive language or gestures, or receiving a second yellow card in the same match.[16] Thus, the only direct mention of potentially injury-related offences is serious foul play, which should be penalized with a red card. In other words, it is clearly evident that according to the *Laws of the Game*, yellow and red cards are primarily awarded for other reasons than to protect players from injury, although it is frequently claimed that the rules of football are written to protect the players from injuries and incidents with a high risk of injury.[10] When examining the results of the present study, which shows that a red card was given for only two injury-related offences during the entire season, this becomes even clearer.

These findings indicate that there is a need for more specific information about the injury mechanisms in tackling duels and heading duels, including the mechanisms for specific injury types such as head injuries and knee and ankle ligament injuries. This information could be used to amend the laws of the game to penalize behavior known to cause injuries, in the same way that FIFA introduced a new rule before the 1998 World Cup. Tackles from behind were classified as serious foul play and would lead to an immediate red card and expulsion from the game. We are convinced that the rules could be further improved to protect players against dangerous play, but at present we are limited by lack of specific information on the mechanisms for even the most common injury types.

It is questionable, however, whether the penalties awarded are sufficient to have a deterrent effect—even if more specific rules to prevent players from dangerous play were put in place and the rule interpretation by referees were perfect. Some national leagues have introduced postgame video review, strict fines, and disqualifications from future games for intentional, serious foul play, and we think this is an important measure to prevent violent conduct. However, it may be that the existing penalty system is too steeply graded. It seems that a free kick or yellow card has no deterrent effect since as a rule they have no bearing on the result of the game (unless it is a penalty kick or the second yellow card in the same game). In contrast, a red card should have a clear deterrent effect, but as shown in the present study, it is not being used to prevent injuries. In many—if not most—cases, a red card may have a direct bearing on the result of the game, and therefore the referee may hesitate to expel players, especially early in the game. We would argue that there is a need for an intermediate disciplinary sanction, sufficiently strict to affect player behavior significantly but not so strict that it would rarely be used.

In lower level regional adult divisions and youth football divisions in Denmark, cautionable offences where a yellow card is shown automatically also lead to a 10-minute temporary expulsion from the game. This rule was originally introduced to reduce the workload and the cost of administration connected to the previous system in which yellow cards, when receiving two or three, led to suspension from forthcoming matches. A 10-minute suspension introduced at all levels of football, similar to the existing rules of other sports such as ice hockey, basketball, lacrosse, and team handball, could possibly contribute to reduce aggressiveness in matches, if used for specific fouls associated with a high risk of injury. Whether a 10-minute expulsion should replace the yellow card or come in addition to the existing disciplinary sanctions, or whether the suspension period should be shorter or longer, needs to be discussed further. However, through a 10-minute expulsion the player(s) and the team(s) will have to expiate the sanction immediately, which may influence the actual match both by "cooling down" the players and at the same time also giving the fair-playing team an advantage that could even have an impact on the result of the match. We would argue that such a change in the laws of football could contribute to a safer but still as entertaining and spectacular sport.

CONCLUSION

In this study, we found that less than one-third of the injuries seen on video and about 40% of the incidents with a high risk of injury resulted in a free kick awarded by the referee. Only about 1 in 10 of the free kicks given for the exposed player resulted in either a yellow or a red card. Second, there was a good correlation between the decision of the match referee and the referee panel, and the match referee was neither too lenient nor too strict in his rule interpretation. There may be a need for an improvement of the laws of the game to protect players from dangerous play.

ACKNOWLEDGMENT

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Paper IV

Video Analysis of the Mechanisms for Ankle Injuries in Football

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Background: Although ankle sprains are frequent in football, little is known about their mechanisms.

Purpose: To describe the injury mechanisms for ankle injuries in male elite football.

Study Design: Prospective cohort study.

Methods: Videotapes and injury information were collected for 313 of 409 matches from Norwegian and Icelandic elite football during the 1999 to 2000 seasons. Video recordings of incidents that resulted in ankle injuries were analyzed and cross-referenced with injury reports from the team medical staff.

Results: A total 46 acute ankle injuries were reported to have occurred, that is, 4.5 injuries per 1000 match hours. Of these, 26 (57%) were identified on the videotapes. Two mechanisms thought to be specific to football were found: 1) player-to-player contact with impact by an opponent on the medial aspect of the leg just before or at foot strike, resulting in a laterally directed force causing the player to land with the ankle in a vulnerable, inverted position; and 2) forced plantar flexion where the injured player hit the opponent's foot when attempting to shoot or clear the ball.

Conclusions: Systematic video analysis provides detailed information on the mechanisms for ankle injuries in football—for lateral ligament sprains and for the condition dubbed "footballer's ankle."

Keywords: biomechanics; video recording; footballer's ankle; incidence; ligament injury; anterior ankle impingement syndrome

Football is responsible for between one-fourth and one-half of all sports-related injuries in Europe.[6,22,24,26] A direct comparison between studies is difficult because of differences in study design and injury definitions, but the risk of injury is undoubtedly high. The injury incidence among adult male players is estimated to 10 to 35 injuries per 1000 match hours.[14,23] Injury severity is also a concern. In fact, in a recent study, Drawer and Fuller[13] concluded that the risk of acute injury in professional football is unacceptably high when evaluated against accepted occupational health criteria. Thus, attention needs to be directed at how to prevent injuries in football.

Ankle injuries are common among football players, accounting for 11% to 25% of all acute injuries.[11,16,21,29,33,41,52] Despite this, to our knowledge no study has examined the mechanisms for ankle injuries in football in detail. Since football is a contact sport requiring a variety of skills, including running, jumping, passing, shooting, kicking, dribbling, turning, heading, and tackling,[15,23] the mechanisms may differ from the inversion injuries typically seen among runners.[18]

Although the lateral ligament complex is the most commonly injured structure, an injury type thought to be specific to football has also been described. Morris[35] and later McMurray[34] originally described a condition referred to as "athlete's ankle" and "footballer's ankle" with talotibial osteophyte formation at the anterior joint capsule. Although this condition—later also referred to as "anterior ankle impingement syndrome"—is a common cause of anterior ankle pain,[17,38,44] the exact cause is unknown. Three different hypotheses have been suggested to explain the formation of osteophytes. First, recurrent maximal plantar flexion and stretching of the joint capsule from repetitive kicking has been suggested to result in traction spurs.[8,32,34] Second, repetitive kicking of the football ball is hypothesized to cause direct damage to the rim of the anterior ankle cartilage, resulting in inflammation, scar tissue formation, and calcification.[49] Finally, repetitive forced dorsiflexion causing minor fractures due to impacts between the bone surfaces of the anterior tibia and the talus has been suggested to cause exostoses to develop on the anterior edge of the tibia and talus.[39]

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A limitation with epidemiological studies is that the injury information is based on postinjury player interviews or medical staff reports.[2,21,22,36,42] However, determining the injury mechanism based on reports from the injured player or their medical staff is difficult. This approach may result in recall bias, and since injuries happen quickly, the player may not even be able to provide an accurate description of how the injury occurred. Since two players can be expected to be involved in the injury situation, at least in many cases, the injured player may not always be fully aware of what actually caused the injury.

A more revealing approach may be to examine videotapes of actual ankle injury situations to describe the mechanisms leading to injury. Thus, the objective of this study was to describe the specific injury mechanisms for ankle injuries in elite male football using video recordings.

METHODS

Videotapes and injury information were collected prospectively from the Norwegian professional football league during the 2000 season and from the elite division in Iceland during the 1999 and 2000 seasons.

The Norwegian Broadcasting Corporation (NRK) and TV2 Norway secured a weekly delivery of DVC pro or Beta SP–quality videotapes from the Norwegian professional football league, and Beta SP–quality videotapes were in the same way made available from the Sports Department of the Icelandic National Broadcasting Service–Television. National or regional television-production teams with one to three cameras were responsible for all recordings in Iceland and most of the recordings in Norway, although 20 matches from Norway were live broadcasts covered with six cameras.

Video recordings from 313 of 409 regular matches (77%), 174 of 182 (league matches only) in Norway (96%), and 139 of 227 (121 league and 18 cup matches) in Iceland (61%) were made available from the television companies. Of these, 296 covered the match in full, whereas for 17 matches the tapes covered 73 minutes on average (range, 36 to 87 minutes). This corresponds to 464.5 match hours, that is, 10,219 player hours. The tapes were reviewed to identify incidents, that is, all situations where the match was interrupted by the referee, one or more players laid down on the pitch for more than 15 seconds, and the player(s) appeared to be in pain or received medical treatment.[1] The incidents, including the play leading up to each of them, were transferred to a master videotape for further analysis.

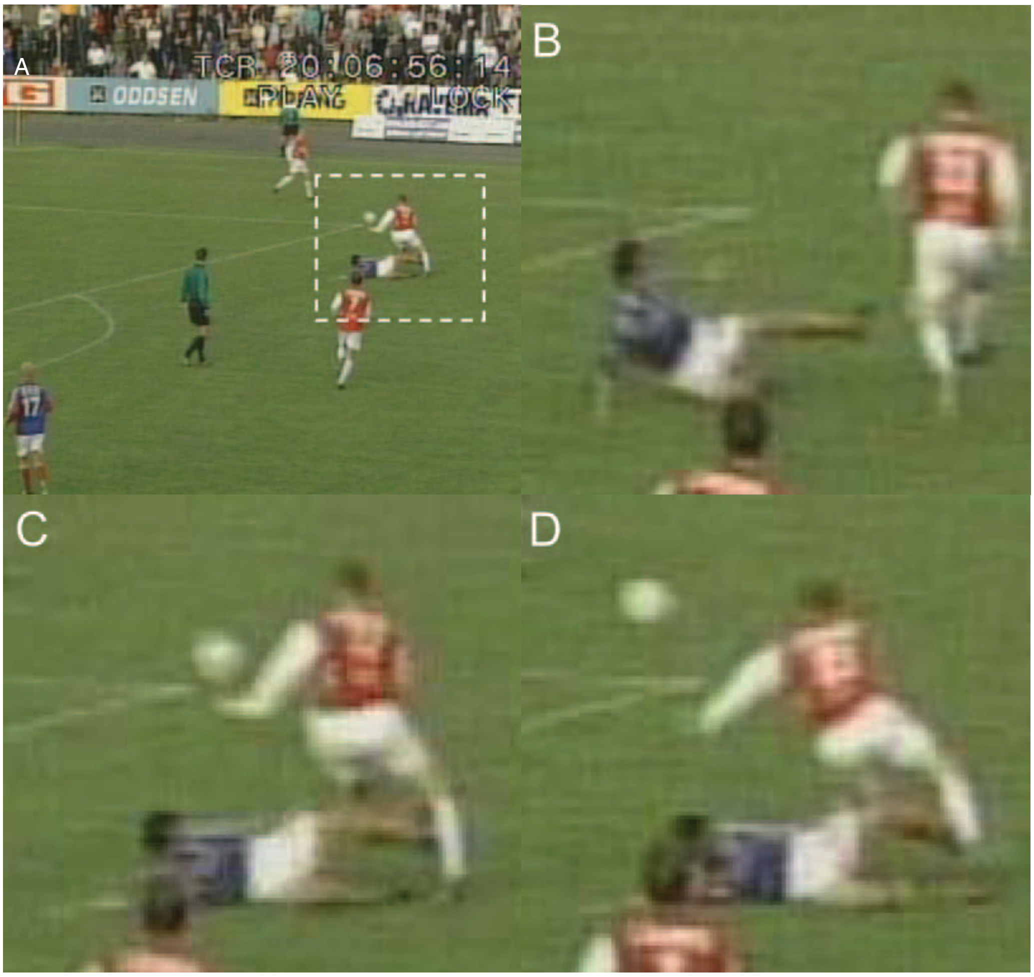

Figure 1. Case 3. A, overview of the playing situation; B, close-up of the injured player (in red) dribbling the ball prior to the tackle; C, the opponent player hits the injured player on the medial side of the right leg, whereupon the injured player transfers his weight fully to his right ankle while it is in an inverted position; D, the moment just after the ankle injury.

The medical staff of each club collected the injury information on all acute injuries that occurred during the season. An injury was recorded if the player was unable to participate in training or match play for at least 1 day following the incident. The incidence of injuries has been expressed as the number of injuries per 1000 match hours. Injuries were classified as minor when the player could not practice football normally or play matches for 1 to 7 days, moderate if absent for 8 to 21 days, and serious if absent for more than 21 days.[23,30] All players with an A-squad contract were covered by the injury registration. A standardized injury questionnaire was used, and reports were collected on a monthly basis. The form included information on the date of injury as well as the time during the match when the injury occurred. Furthermore, the injury location was registered, and injuries were classified as contusions, sprains, strains, fractures, or lacerations. Finally, each injury received a specific diagnosis using Orchard codes.[37]

Each incident identified on the videotapes was cross-referenced with the injury reports from the team medical staff. In addition, the original tapes were reexamined to find incidents that had not been identified in the first video review. The recordings of all ankle injuries were transferred to a separate master videotape. Each recording was edited to include three sequences, that is, the entire playing situation including the play leading up to the injury at normal speed, one repetition of the injury, and a slow-motion close-up repeat of the injury.

A specific ankle questionnaire was developed to describe the injury mechanism and the events leading up to the injury. The questionnaire included the case number and the side injured in each case. The variables used in the questionnaire were defined as follows: 1) the primary injury mechanism: tackling with the foot on the ground, tackling with the foot in the air, clearing or shooting, running, landing after jump, or other; 2) the movement intensity of the player at the moment of injury: high intensity (that is, sprinting and moderate intensity running) or low intensity (that is, jogging, walking, and standing); 3) whether the injured player was actively tackling an opponent (active) or whether he was being tackled by an opponent (passive); 4) the tackling types used by the injured player and the opponent: sliding tackle, locking tackle of the foot or leg, stepping, kicking, dribbling, or other; 5) whether it was a late tackle (that is, whether the tackle occurred after the ball had been passed by the injured player); 6) contact with another player: before the injury, at the time of injury, after the injury, or no contact; 7) the main

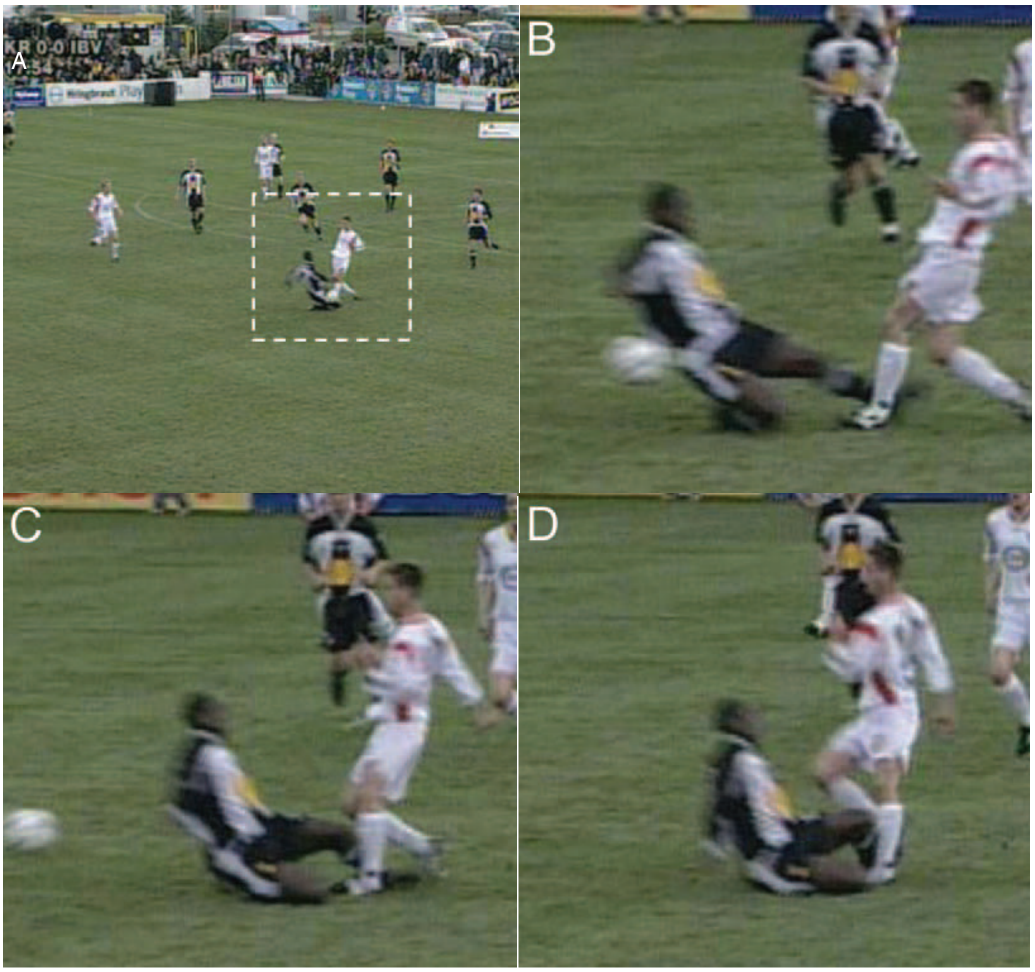

Figure 2. Case 6. A, overview of the playing situation. B, close-up from a slightly different view. The injured player (in white) has passed the ball and the opponent player makes a sliding tackle and hits the injured player on the medial side of the left leg (late tackle). C, the injured player transfers his weight fully to his ankle while this is in an inverted position. D, the moment just after the ankle injury.

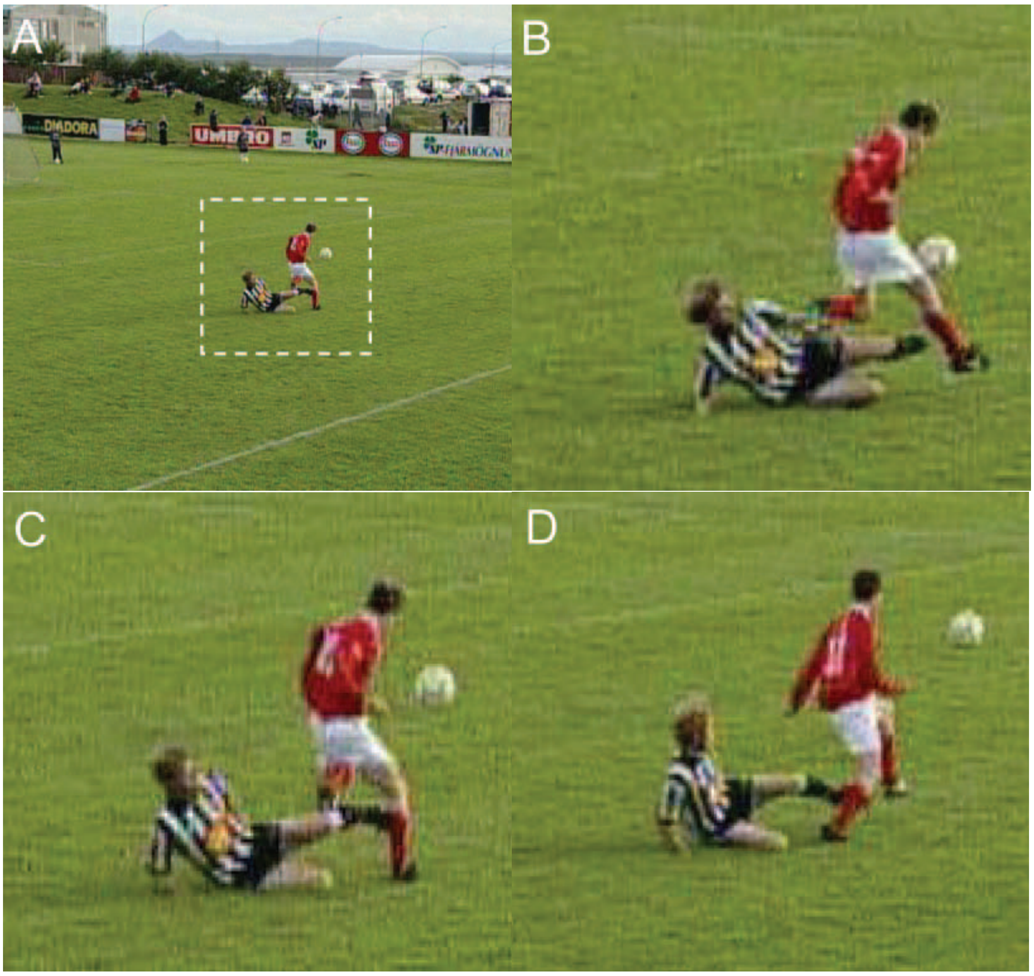

Figure 3. Case 4. A, overview of the playing situation. B, close-up of the situation. The injured player (in red) tries to avoid a tackle with the opponent player by jumping over him. C, opponent player hits the injured player on the medial side of the right leg at the moment the foot hits the ground. He tries to avoid the ankle injury by outwardly rotating the knee. D, the ankle is forced into an inverted position, the knee position can no longer compensate, and the player puts his full weight on it.

direction of ankle motion: eversion (pronation, external rotation, dorsiflexion), inversion (supination, internal rotation, plantar flexion), forced plantar flexion, or could not be evaluated; 8) point of impact on the injured player: medial side of the ankle or leg, lateral side of the ankle or leg, forefoot of the injured player, or other; 9) position of the injured foot at the time of injury: on the ground or in the air; 10) degree of weightbearing at the time of injury: full, moderate, or minimal; and 11) decision made by the match referee: no foul, free kick for or against the injured player, and whether the free kick resulted in a yellow or red card.

The master videotape was analyzed independently by two experienced specialists in sports medicine (TEA and RB). Disagreements were discussed in a consensus meeting, where the video recordings were reevaluated and a final decision was made.

RESULTS

Incidents and Injuries

During the 313 matches available on videotape (174 from the Norwegian professional league and 139 from the Icelandic elite division), 712 incidents were recorded (425 from Norway and 287 from Iceland), that is, 69.5 incidents per 1000 match hours (75.5 per 1000 match hours in Norway and 62.5 in Iceland). A total of 297 acute injuries were reported to have occurred during the same matches by the team medical staff (121 from Norway and 176 from Iceland). This corresponds to an incidence of 29.1 injuries per 1000 match hours (21.5 per 1000 match hours in Norway and 38.4 in Iceland). Of the 297 acute injuries reported, 46 (15%) were ankle injuries (18 from Norway and 28 from Iceland), which corresponds to an incidence of ankle injuries of 4.5 per 1000 match hours (3.2 per 1000 hours in Norway and 6.1 in Iceland). Of these ankle injuries, 26 (57%) were identified on the videotapes (10 from Norway and 16 from Iceland).

Of the 26 ankle injuries, 23 were classified as sprains and 3 as contusions (cases 8, 15, and 19; see Table 1).

Video Analysis

The video analysis of the 26 ankle injuries showed that 14 occurred during tackling, 4 during clearing or shooting, 4 during running, and 2 during landing after heading, whereas 2 were classified as other injury mechanisms

TABLE 1
Results From Video Analysis of the Mechanisms for Ankle Injuries in Elite Football[a]

Case number	Primary mechanism	Injured player	Late tackle	Action of injured player	Timing of contact	Injury mechanism	Contact	Location of contact	Foot location	Decision made by the referee	Severity of injury
1	Tackling	Passive	Yes	Dribbling	Before	Inversion	Foot/leg	Medially	On the ground	No foul	Minor
2	Tackling	Passive	Yes	Dribbling	During	Inversion	Foot/leg	Medially	On the ground	Yellow card	Moderate
3	Tackling	Passive	Yes	Dribbling	During	Inversion	Foot/leg	Medially	On the ground	Yellow card	Moderate
4	Tackling	Passive	Yes	Dribbling	During	Inversion	Foot/leg	Medially	On the ground	No foul	Moderate
5	Tackling	Passive	Yes	Dribbling	During	Inversion	Foot/leg	Medially	On the ground	No foul	Minor
6	Tackling	Passive	Yes	Passing	During	Inversion	Foot/leg	Medially	On the ground	Foul for	Minor
7	Tackling	Passive	No	Dribbling	During	Inversion	Foot/leg	Medially	On the ground	Yellow card	Minor
8	Tackling	Passive	No	Dribbling	During	Inversion	Foot/leg	Medially	On the ground	Yellow card	Minor
9	Tackling	Passive	No	Receiving pass	During	Inversion	Foot/leg	Forefoot	On the ground	No foul	Severe
10	Tackling	Passive	No	Receiving pass	During	Eversion	Foot/leg	Forefoot	On the ground	No foul	Minor
11	Tackling	Active	Yes	Tackling	During	Inversion	Foot/leg	Medially	On the ground	No foul	Moderate
12	Tackling	Active	No	Tackling	During	Inversion	Foot/leg	Medially	On the ground	No foul	Minor
13	Tackling	Active	No	Tackling	During	Inversion	Foot/leg	Medially	On the ground	No foul	Minor
14	Tackling	Active	Yes	Tackling	During	Inversion	Foot/leg	Other	On the ground	Yellow card	Moderate
15	Clearing/ shooting	Active	Yes	Kick	During	Cannot be evaluated	Foot/leg	Medially	In the air	No foul	Minor
16	Clearing/ shooting	Active	Yes	Kick	During	Forced plantar flexion	Foot/leg	Forefoot	In the air	Yellow card	Severe
17	Clearing/ shooting	Active	Yes	Kick	During	Forced plantar flexion	Foot/leg	Forefoot	In the air	No Foul	Moderate
18	Clearing/ shooting	Active	No	Kick	During	Forced plantar flexion	Foot/leg	Forefoot	In the air	No foul	Severe
19	Running			Passing	No contact	Inversion			On the ground	No foul	Severe
20	Running			Running	Before	Inversion			On the ground	Red card	Moderate
21	Running			Running	During	Inversion			On the ground	No foul	Minor
22	Running			Running	No contact	Inversion			On the ground	No foul	Minor
23	Landing			Heading	Before	Inversion			On the ground	Foul against	Severe
24	Landing			Heading	Before	Cannot be evaluated			On the ground	No foul	Moderate
25	Other			Dribbling	No contact	Inversion			On the ground	No foul	Moderate
26	Other			Running	During	Cannot be evaluated			On the ground	No foul	Moderate

[a] The horizontal lines indicate the grouping of the injuries into tackling situations, situations in which the injured player was clearing or shooting the ball, running, landing, and other situations.

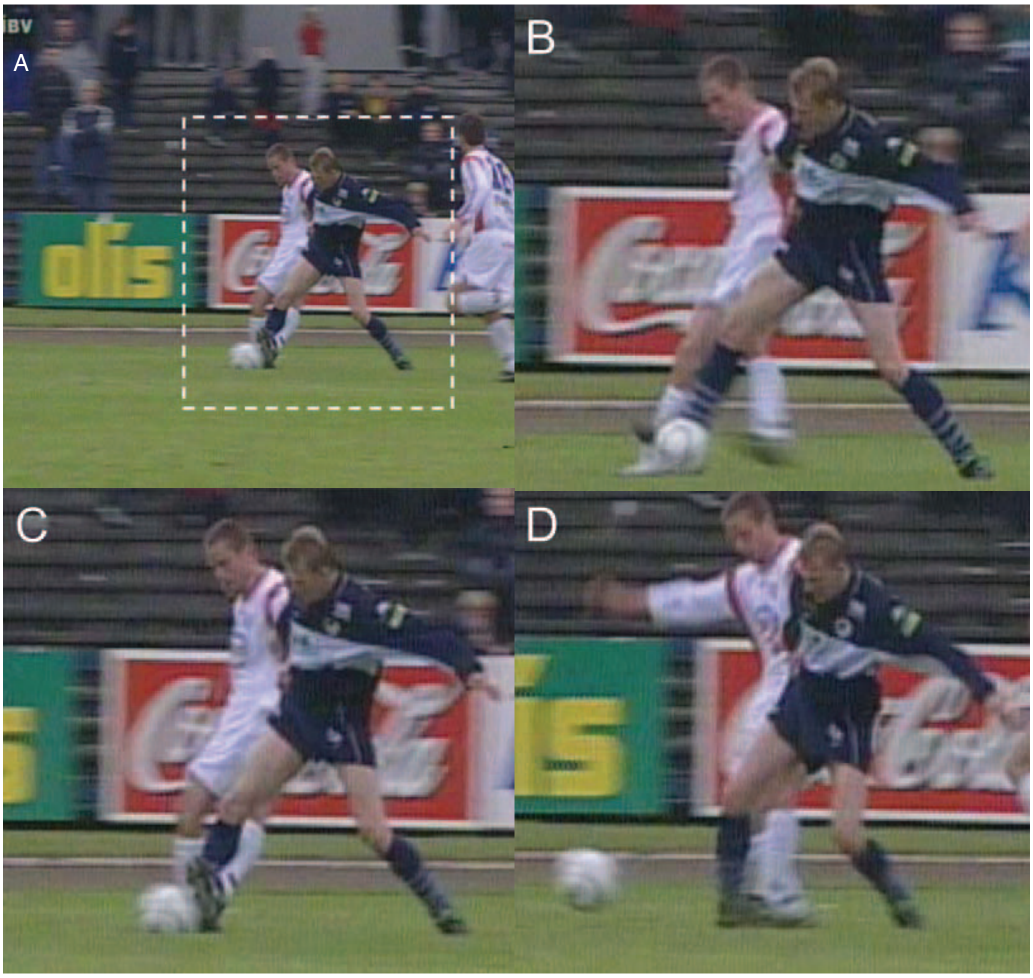

Figure 4. Case 7. A, overview of the playing situation; B, injured player (in blue) is trying to shield the ball from the opponent; C, opponent hits the ball; D, injured player is hit on the medial side of his right leg, forcing it into inversion before bearing weight on it.

(Table 1). Midfielders were injured in 14 cases, strikers in 4, and defenders in 7. The referee awarded no foul in 17 cases, whereas 6 incidents led to a free kick and yellow card, 1 to a free kick and red card, and 1 to a free kick only for the injured player. In 1 incident, a free kick was awarded against the injured player. Of the 11 incidents classified as late tackles (Table 1), a foul was called in 5 incidents. Four of these led to a yellow card.

Tackling Injuries. In 10 of the 14 tackling incidents, the injured player was tackled by an opponent. Of these, 6 were classified as a late tackle; that is, the player was tackled after the injured player had passed the ball. The injured player was dribbling the ball in 7 cases and receiving a pass or passing the ball in 3 cases. In 4 of the tackling incidents, the injured player was actively tackling; 2 of them were classified as late tackles. Of the 14 incidents, all except 1 involved contact between the injured player and the opponent at the moment of injury. Of the 14 tackling injuries, all except 1 were the result of an inversion mechanism. They occurred with the foot of the injured player touching the ground and with contact between the foot of the opponent and the leg of the injured player. In 11 cases, the injured player was hit on the medial side of the foot, whereupon the injured player transferred his weight fully to his ankle while it was in an inverted position (Figs. 1 to 4). In 11 of the 14 incidents, the injured player was moving at high intensity, whereas in 3 he was moving at low intensity. In all cases, the injured player had some part of the injured foot on the ground, and all of the injured players except one were transferring all of their weight to the injured foot at the moment of injury.

Kicking Injuries. Four injuries occurred when the player was attempting to clear the ball or shoot while an opponent tried to block the ball (Fig. 5). In all cases, the injured player was the active part, hitting the opponent's leg while kicking with the foot in an equinus position, resulting in a forced plantar flexion in three cases. The foot position of the final case could not be assessed from the video. All except from one were classified as late tackles. In all case incidents, the injured player was moving with high intensity. None of the players was disturbed at the time of injury.

Running Injuries. Four injuries occurred while the player was running: two while involved with an opponent player and two while alone. All injuries happened when the injured player placed his foot on the ground while it was in an inverted position. The injured player was moving with high intensity at the moment of injury in all four cases.

Other Injuries. Two injuries occurred during landing after a heading duel with an opponent. The final two incidents resulted from other mechanisms. In one case, the

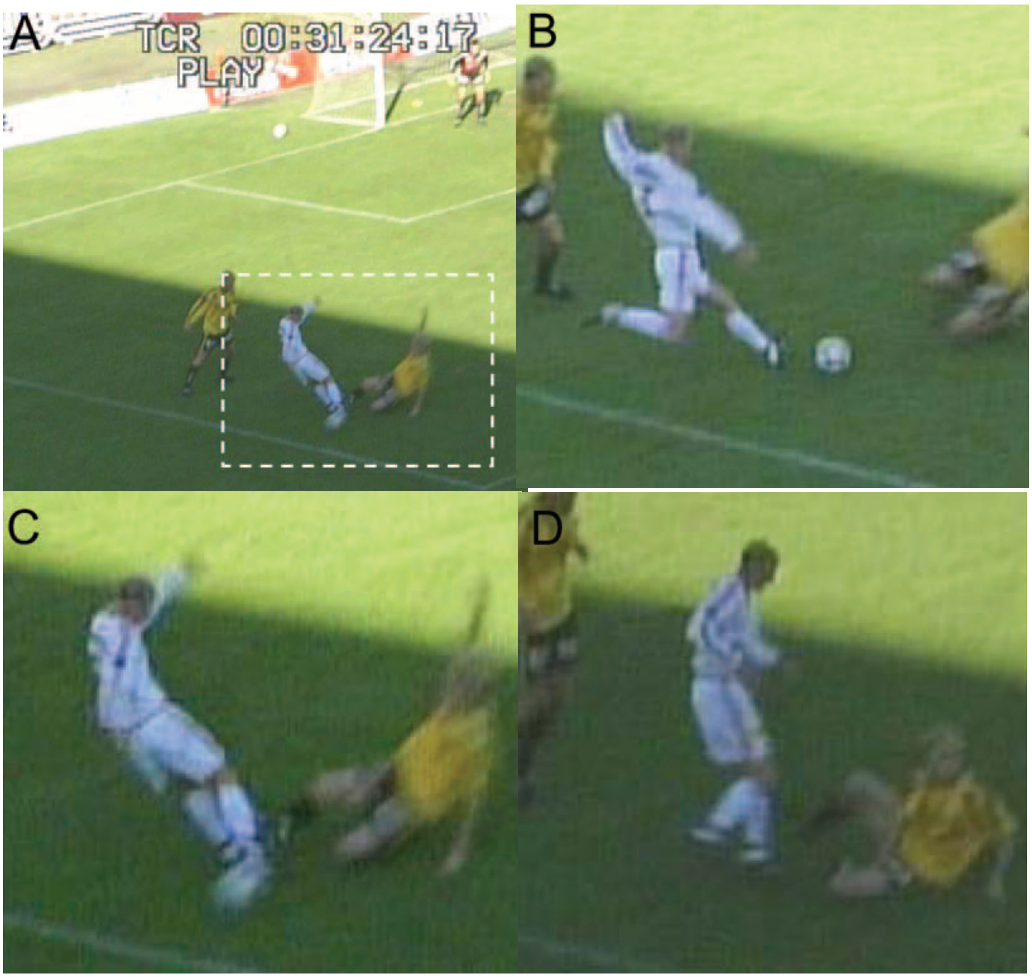

Figure 5. Case 18. A, overview of the playing situation. B, close-up of the situation prior to the contact. Player to be injured (in white) prepares to hit the ball with a forceful kick while opponent comes in with a sliding tackle. C, opponent player hits the ball before the injured player kicks maximally with his right foot, hitting the opponent's foot, and gets injured. D, moment just after the injury.

player was alone and appeared to simply stumble after having received the ball, perhaps resulting from an uneven pitch. The other incident occurred after the injured player was kicked unintentionally in the foot by a teammate.

DISCUSSION

The aim of this study was to describe the mechanisms of ankle injuries in football based on an analysis of video recordings of injuries from Norwegian and Icelandic elite football. A main finding was—as expected—that most injuries resulted from inversion trauma. However, in most cases involving player-to-player contact, accounting for about half of all injuries, the indirect cause of injury appeared to be contact to the medial aspect of the lower leg or ankle. Most likely, this laterally directed force did not produce the injury itself but caused the player to land with the ankle in a vulnerable, inverted position. The other main finding was that we observed four cases in which the injured player hit the opponent's foot with a full-force kick, resulting in forced plantar flexion of the ankle. This mechanism may explain the condition dubbed footballer's ankle.

Methodological Considerations

When interpreting the results of the present study, some obvious limitations must be considered. First, although we had information on the approximate time during the match each ankle injury occurred, we were able to identify only 57% of the acute ankle injuries that were reported by team medical staff to have occurred, even after close scrutiny of the tapes. This leads us to believe that the remaining 43% of the injuries resulted from minor trauma and mechanisms that may have been different from those identified on tape. At least they were more difficult to detect, possibly because they did not result from player-to-player contact or because they occurred outside camera view.

Second, the video recordings used in this study were from matches only. Therefore, only mechanisms for ankle injuries in match play could be evaluated. However, previous studies[2,14,16,20,23,31,36] have shown that most football injuries in elite players occur during match play, as was the case in the present study (data not shown). Whether the mechanisms for training and match injuries differ is unknown, although we would expect there to be fewer late tackles and less foul play during training than in match play.

Another limitation is that the assessment was subjective and qualitative and in some cases based on tapes with less than optimal quality and a limited number of views available. Nevertheless, the main mechanism for tackling injuries appeared to be remarkably consistent between cases, and it was easy to agree on the description and classification of mechanisms. Even keeping the limitations mentioned in mind, a systematic analysis of injury situations from video would seem to be the obvious approach toward a more detailed understanding of the mechanisms for sports injuries, providing more reliable information than retrospective player interviews.

However, it should be noted that this study was conducted on elite male football players. There may be differences in injury mechanisms between these players and other player populations (for example, younger players, female players) that warrant attention in future studies.

Injury Mechanisms

The majority (88%) of the ankle injuries we were able to identify on video resulted from contact with an opponent. This is in contrast to a study among youth and adult players participating at various competition levels in one football club in Denmark.[36] Based on reports from the coaches, they found that ankle sprains occurred equally during tackling and running. However, Chomiak et al.[11] in a similar study in the Czech Republic found that 68% of the ankle injuries were due to body contact, and in a recent study among professional English football players 59% of the ankle injuries were reported to be caused by contact mechanisms.[52] Although a direct comparison of the results is difficult, it seems reasonable to conclude that challenging ball possession is a situation with a high risk for ankle injuries.

An inversion mechanism was found in all but one of the tackling injuries, all running injuries, and in one of two after landing after a heading duel. Based on questionnaire data, inversion of the ankle has been described to be the most frequent injury mechanism for ankle sprains in football[11,47] and among runners.[18] Studies of ankle sprains in volleyball have shown the main mechanism to be landing on the foot of an opponent or teammate after blocking or attacking at the net.[4] From the present study, it appears that there is a specific mechanism for football injuries as well. The injured player received a laterally directed hit on the medial side of the ankle or lower leg, whereupon landing in a supinated position led to an inversion injury (Fig. 6). In some cases, it appeared that the players tried to avoid the ankle injury by flexing their knee and externally rotating their thigh to avoid putting weight on the ankle joint. However, when he no longer could compensate, the player had to put weight on the ankle and an injury occurred. Ankle inversion torques that result in lateral ligament lesions are thought to arise primarily in situations in which the ankle goes through a transition from an unloaded to a loaded condition.[46] Other biomechanical studies have shown that the anterior talofibular ligament (ATFL) is the first ligament to be tensed and so the first to rupture when forced inversion of the ankle occurs.[7,10]

Figure 6. Typical mechanism for lateral ligament injury in football: opponent contact to the medial side of the leg, causing the player to put weight on an inverted ankle. Illustration reproduced with permission by ©Oslo Sports Trauma Research Center/T. Bolic.

Broström[9] and van der Ent[48] have presented data from surgery showing that half of all ankle sprains were isolated ATFL tears and about 25% were combined ATFL and calcaneofibular ligament tears. In other words, the findings from clinical studies, biomechanical research, and surgical findings correspond well with the present findings, suggesting that the typical football mechanism is an inversion sprain after a laterally directed hit on the medial side of the ankle or lower leg.

In three of the four incidences classified as "clearing or shooting," the injured player was actively kicking with the foot placed in a forced plantar flexion. It may be hypothesized that this is the mechanism whereby footballer's ankle occurs, even if the number of cases is small in this study. McMurray,[34] after Morris[35] first had described this specific condition, suggested that kicking the ball with the foot usually in a position of full extension leads to strain on the anterior capsule of the ankle joint, eventually giving rise to osteophyte formation. The mechanism for footballer's ankle is controversial, and three theories exist to explain the formation of osteophytes. Recurrent maximal plantar flexion and stretching of the joint capsule from repetitive kicking is suggested to result in traction spurs.[8,32,34] Van Dijk et al.[49] suggested that repetitive kicking of the football ball caused direct damage to the anterior joint cartilage, resulting in inflammation, scar tissue formation, and calcification. Finally, repetitive forced dorsiflexion causing minor fractures due to impacts between the bone surfaces of the anterior tibia and the talus has been suggested to cause exostoses to develop on the anterior edge of the tibia and talus.[39] The present video analysis suggests that the first theory, with forced plantar flexion, may be the cause of footballer's ankle (Fig. 7).

Perspectives for Injury Prevention

Ankle sprains can be prevented.[5,43,51] The protective effects of taping and bracing have been shown persuasively in football, although only for players with previous ankle injury.[42,45] The most important risk factor for ankle injuries is history of a previous sprain.[3] Neuromuscular function is reduced in athletes with persistent instability complaints after injury[25,28,46] and even in the immediate recovery period after an acute injury.[27] How tape and orthoses work is uncertain, but they may simply enhance neuromuscular control of the ankle joint. This view is corroborated by the fact that their effect is limited to players with previous injury,[40,42,45] where proprioceptive function is reduced,[25,28,45] and that orthoses do not seem to restrict inversion enough to substantiate their prophylactic effect.[12,50] If the protective effect were mechanical, one would expect an effect in healthy ankles as well. It is also important to note that neuromuscular control in chronically unstable ankles can be restored with a balance board training program[19] and that such a program appears to reduce the risk of reinjury at the same level as healthy ankles.[45]

The present study shows that a significant proportion of ankle injuries are contact injuries resulting from a medial blow to the ankle or lower leg, a mechanism where neither balance training nor ankle support would be expected to have a protective effect. However, as mentioned above, it may be that the laterally directed blow is not the direct cause of injury but merely serves to put the ankle in a vulnerable position when landing or running. Thus, increased neuromuscular control through training or bracing could aid the player in correcting foot position before putting weight on the ankle, at least in some cases.

The role of fair play and proper refereeing is frequently discussed in injury prevention. Based on our assessment of the videotapes, there were a number of cases in which injuries resulted from late tackles without penalty to the offender. In some cases, our impression was that these were intentional, professional fouls. Although we acknowledge that the task of enforcing the laws of the game is difficult—the match referee not having the benefit of video replay—we would argue that the present findings show that there is a need for stricter enforcement of the laws of the game in tackling situations. A number of measures can potentially be effective, including improved referee training focusing on situations with injury potential, immediate or delayed video review by the match referee in such cases, more specific wording of the laws of the games regarding late tackles, and stricter penalties for this type of rule violation. It appears that free kicks or even yellow cards do not have the desired deterrent effect on player behavior, and we therefore suggest that the introduction of timed suspensions (for example, 10 minutes for dangerous play) be considered. Such suspensions would—unlike free kicks or yellow cards—in many cases directly influence match outcome and may be a more effective disincentive on dangerous foul play.

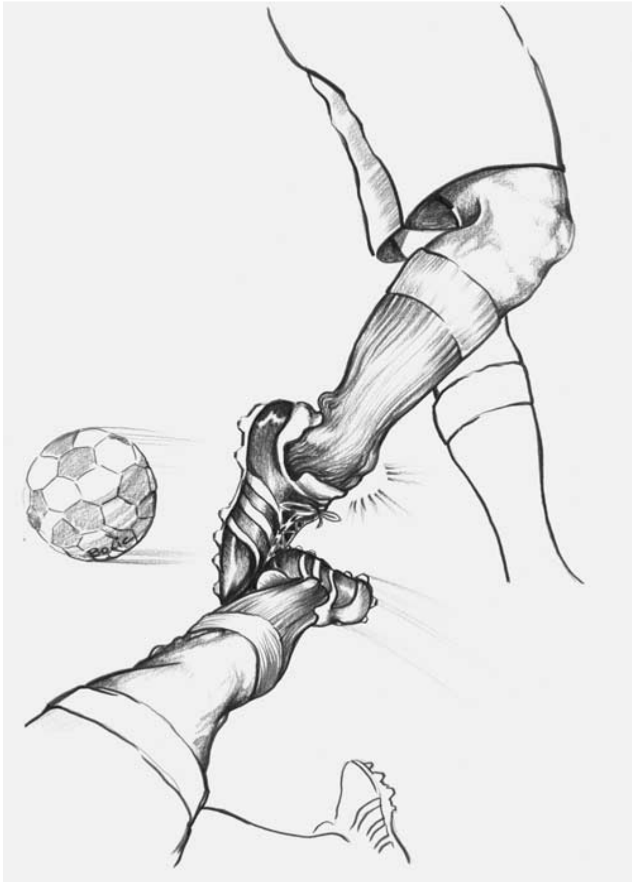

Figure 7. Probable mechanism for development of footballer's ankle. Illustration reproduced with permission by ©Oslo Sports Trauma Research Center/T. Bolic.

CONCLUSION

This study showed that a thorough video analysis seems to give detailed information about mechanisms of ankle injuries in football. The most frequent injury mechanism found was player-to-player contact with impact on the medial aspect of the lower leg or ankle of the injured player. Most likely, this laterally directed force caused the player to land with the ankle in a vulnerable, inverted position. In addition, we observed four cases in which the injured player hit his opponent's foot, resulting in forced plantar flexion of the ankle. This mechanism may explain the condition dubbed footballer's ankle.

ACKNOWLEDGMENT

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Paper V

ORIGINAL ARTICLE

Mechanisms of head injuries in elite football

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Objectives: The aim of this study was to describe, using video analysis, the mechanisms of head injuries and of incidents with a high risk of head injury in elite football.

Methods: Videotapes and injury information were collected prospectively for 313 of the 409 matches played in the Norwegian (2000 season) and Icelandic (1999 and 2000 season) professional leagues. Video recordings of incidents where a player appeared to be hit in the head and the match was consequently interrupted by the referee were analysed and cross referenced with reports of acute time loss injuries from the team medical staff.

Results: The video analysis revealed 192 incidents (18.8 per 1000 player hours). Of the 297 acute injuries reported, 17 (6%) were head injuries, which corresponds to an incidence of 1.7 per 1000 player hours (concussion incidence 0.5 per 1000 player hours). The most common playing action was a heading duel with 112 cases (58%). The body part that hit the injured player's head was the elbow/arm/hand in 79 cases (41%), the head in 62 cases (32%), and the foot in 25 cases (13%). In 67 of the elbow/arm/hand impacts, the upper arm of the player causing the incident was at or above shoulder level, and the arm use was considered to be active in 61 incidents (77%) and intentional in 16 incidents (20%).

Conclusions: This study suggests that video analysis provides detailed information about the mechanisms for head injuries in football. The most frequent injury mechanism was elbow to head contact, followed by head to head contact in heading duels. In the majority of the elbow to head incidents, the elbow was used actively at or above shoulder level, and stricter rule enforcement or even changes in the laws of the game concerning elbow use should perhaps be considered, in order to reduce the risk of head injury.

Football is the only contact sport that exposes a large number of participants to purposeful use of the head for controlling and advancing the ball.[1] Based on a series of cross sectional studies[2 3–5]on active and older retired Norwegian football players, using neurological examinations, neuropsychological tests, computer tomography (CT) scans, and electroencephalography (EEG) examinations, Tysvær *et al*[5] postulated in 1991 that heading the ball could lead to chronic brain injury such as that seen in boxers.[6] Since then, several cross sectional studies have indicated that football can cause sustained measurable brain impairment,[7–11] and this has caused significant concerns over the effects of repetitive heading in soccer.[12] In response to this, protective headgear has been manufactured for football; however, no standards exist and it is still unclear whether these devices would protect players from blows to the head. Naunheim *et al*[13] showed in a recent experimental study that headgear has little ability to reduce impact when heading, but they suggest that headbands may play a role in attenuating the impact for more forceful blows at the highest speeds.

However, it should be noted that in the absence of longitudinal cohort studies it is not possible to decide whether repetitive heading is the cause of the cognitive deficiencies observed among football players. In a recent review, Kirkendall *et al*[1] state that to date it appears that heading is not likely to be a significant factor, but that the reported deficits are more likely to be the result of accidental head impacts that occur during the course of the matches.

Head injuries account for 4–22% of all football injuries.[14–19] However, this figure incorporates all types of head injuries, including facial fractures, lacerations, and eye injuries. The rate of brain injuries is difficult to assess because of the problem of defining and grading concussions.[1] Nevertheless, it appears that the higher the level of play and the more competitive the league, the higher the incidence of concussions.[18–21]

There is limited information on the mechanisms of head injury in football.[1] Studies based on player reports or reports by team medical personnel show that injuries mainly result from contact with other players.[22–28] Boden *et al*[19] prospectively studied collegiate female and male players and found that about 70% of the concussions occurred during games, and that head to head contact was the most frequent mechanism of injury, followed by head to ground and head to other body parts (foot, knee, elbow). Furthermore, they found that none of the concussions resulted from intentional heading of the ball.[19]

However, as acute injuries occur in a split second, it may be difficult for players or team medical staff to provide exact information on their mechanisms. A different approach is needed to describe the circumstances leading to head injuries more precisely. Video analysis has been used to study the mechanisms of concussive injury in elite national Australian rules football,[29 30] but this approach has not been used in association football. Therefore, the aim of the present study was to describe the mechanisms of head injuries and incidents with a high risk of head injury in elite football using video analysis.

METHODS

Videotapes and injury information were collected prospectively from the Norwegian professional football league during the 2000 season (April–October) and from the elite division in Iceland during the 1999 and 2000 seasons (May–September).

The Norwegian Broadcasting Corporation (NRK) and TV2 Norway secured a weekly delivery of DVC pro or Beta SP quality video tapes from the Norwegian professional football league, and Beta SP quality video tapes were also made available by the Sports Department of the Icelandic National Broadcasting Service (Television) from the Icelandic league. National or regional television production teams with 1−3 cameras were responsible for all recordings in Iceland and most of the recordings in Norway, although 20 matches from Norway were live broadcasts covered with six cameras.

Video recordings from 313 matches of 409 regular league or cup matches (77%), 174/182 (league matches only) in Norway (96%) and 139/227 (61%) in Iceland were available from the television companies. Of these matches, 296 were covered in full, whereas in 17 matches the tapes covered 73 minutes on average (range 36 to 87). This corresponds to a total of 464.5 match hours, or 10 219 player hours.

The tapes were reviewed to identify incidents where the player appeared to be hit in the head, the match was interrupted by the referee, and one or more players were lying down on the pitch for more than 15 s. In addition, the player(s) had to appear to be in pain or receive medical treatment.[31] The incidents, including the entire playing sequence leading up to each of them, were transferred to a master videotape for further analysis. Each recording was edited to include three sequences: the entire playing situation including the play leading up to the injury at normal speed, one repetition of the injury, and a slow motion close up repeat of the injury.

The medical staff of each club collected the injury information on all acute injuries that occurred during the season. An injury was recorded if the player was unable to participate in training or match play for at least 1 day following the incident. Concussion was defined according to the clinical practice in Norway and Iceland—that is, a concussive injury was registered when a player either suffered loss of consciousness or had post-concussive amnesia for the incident. The incidence of injury was expressed as the number of injuries per 1000 player hours. Injuries were classified as minor when the player could not practice football normally or play matches for 1–7 days, moderate if absent for 8–21 days, and serious if absent for >21 days.[32 33] All players with an A squad contract were covered by the injury registration. A standardised injury questionnaire was used and reports were collected on a monthly basis. The form included information on the date of injury, as well as the approximate time during the match that the injury occurred. The injury location was registered and injuries classified as contusions, sprains, strains, fractures, or lacerations. Finally, each injury received a specific diagnosis using Orchard codes.[34]

Each incident identified on the videotapes was cross-referenced with the reports of head injuries from the team medical staff, and the original tapes were re-examined to find any head injuries that had not been identified in the first video review. The master videotape with all of the head incidents was analysed independently by three of us (TEA, LE, and RB), who are experienced specialists in sports medicine. Disagreements were discussed in a consensus meeting, where the video recordings were re-evaluated and a final decision was made.

A specific questionnaire was developed to describe the injury mechanism and the events leading up to the head injury. The variables used in the questionnaire were defined as follows: (*a*) the number of players involved in the incident (one, two, or three or more); (*b*) if more than one player was involved, were they team mates, opponents, or both; (*c*) type of playing action: heading duel, hit by the ball, kicked by opponent or team mate, running duel, tackling duel, positioning/forechecking, goalkeeping, or other; (*d*) what object hit the head: head, elbow, arm/hand, foot, knee, ball, shoulder, ground, goalpost, or other; (*e*) if the elbow or arm/hand hit the head, was the elbow above, at, or under shoulder level; (*f*) for elbow/arm/hand cases, was the arm use passive, active, or an intentional strike; (*g*) if the foot hit the head, was it a high kick or had the injured player been bending down; (*h*) the point of impact: face, forehead, side of the head, back of the head, or cervical spine; and (*i*) for head to head heading duels, the relative horizontal speed of the colliding players; very high (both players moved at maximum or near maximum speed), high (one of the players moved at maximum speed, the other player was jogging), moderate (both players were jogging or one near maximum, the other moving slowly or standing still), or low (one or both players were standing, or one jogging or standing still).

Statistics

Differences in rates between Norway and Iceland were assessed using a Poisson regression model with indicator for country as independent variable and number of injuries or incidents as dependent variable. Differences in proportion of point of impact between two body parts were tested by χ^2 test without any adjustments for multiple comparisons.

RESULTS

Incidents and injuries

During the 313 matches available on video (174 from the Norwegian professional league and 139 from the Icelandic elite division), 192 head incidents were recorded (124 from Norway and 68 from Iceland), a total of 18.8 per 1000 player hours (22.0 per 1000 player hours in Norway and 14.8 in Iceland, $p = 0.009$). Of the 297 acute time loss injuries reported, 17 (6%) were head injuries (11 from Norway and six from Iceland; non-significant), which corresponds to an incidence of 1.7 per 1000 player hours (2.0 per 1000 player hours in Norway and 1.3 in Iceland; non-significant). When comparing the ratios of the head injuries to head incidents between the two countries, Iceland had rates 2.15 times higher than Norway ($p<0.0001$).

Of the 17 head injuries reported, 16 were identified on the videotapes (10 from Norway and six from Iceland). Of the 16 head injuries identified on video, five were classified as concussions (0.5 per 1000 player hours), two as nasal fractures, two as mandibular fractures, four as lacerations to the head or the face, one as a contusion, and three as muscular strains to the neck. The one injury not identified on video was a muscular strain to the neck. One of the facial fractures and one of the lacerations also resulted in injuries to the teeth. Eleven injuries were classified as minor, two as moderate, and three as serious.

Video analysis

The video analysis revealed 192 incidents involving head contact. In these incidents the most common playing action 9112 cases; 58%) was a heading duel (fig 1). The opponent body part that most often hit the injured player was the elbow (66 incidents; 34%), and in addition 13 cases were

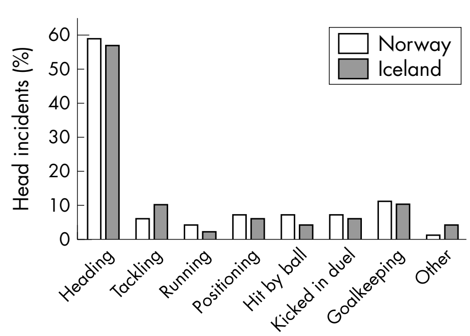

Figure 1 The primary mechanism causing trauma to the head in elite football in Norway (n = 124 incidents, white bars) and in Iceland (n = 68 incidents, grey bars).

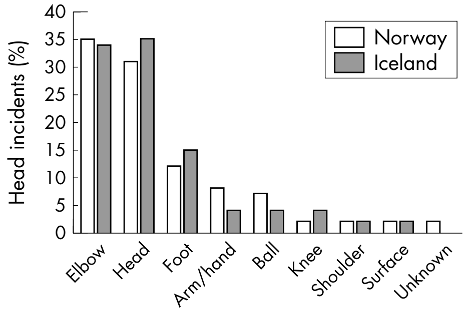

Figure 2 The opponent body part hitting the head of the exposed player in Norway (n = 124 incidents, white bars) and in Iceland (n = 68 incidents, grey bars).

caused by contact with the arm or hand (7%) and four cases by the shoulder (2%) (fig 2). In other words, a total of 83 cases (43%) were caused by impact from the upper extremity. The point of impact on the head was the face in 57% of the cases, the back of the head in 22%, the side of the head in 13%, and the forehead in 6% (table 1). The point of impact was different between head and elbow incidents ($p<0.01$). In addition, the point of impact was different between head incidents and the other modes (elbow, arm/hand, foot, and ball; all $p<0.001$).

Elbow, arm, or hand to head incidents

In 79 of the incidents (five injuries) the primary mechanism was a blow from the elbow (66) or the arm/hand (13) to the head (fig 3). Of these, in 39 cases (49%) the arm of the player causing the incident was above shoulder level and in 28 cases (35%) it was at shoulder level. The use of the elbow was considered to be active in 61 of these incidents (77%), and 16 incidents were assessed to be intentional strikes (20%). The point of impact of the elbow or arm/hand on the head was the face (73%) in 58 cases, the back of the head (15%) in 12, and the side of the head in 8 cases. Only one player was hit in the forehead.

In 53 (67%) of these incidents the decision made by the referee was ''no foul'', while a free kick for the exposed player was awarded in 21 of the cases (fig 4). Of the free kicks awarded, four resulted in a yellow card and four in a red card. Of the five injuries occurring from blows by the elbow, arm, or hand, there was one concussion, one mandibular fracture, one facial laceration, and one neck muscle strain. Three of the injuries were minor, one was moderate, and one serious.

Table 1 The body part of the opponent hitting the exposed player versus the point of impact on the head (n = 192 head incidents and 16 injuries)

	Part of the head hit					
Body part	Face	Back of the head	Side of the head	Forehead	Unknown	Total
Head	19 (–)	22 (3)	15 (1)	6 (1)	– (–)	62 (5)
Shoulder	3 (–)	– (–)	1 (–)	– (–)	– (–)	4 (–)
Elbow	49 (3)	10 (–)	6 (–)	1 (–)	– (–)	66 (3)
Arm/hand	9 (2)	2 (–)	2 (–)	– (–)	– (–)	13 (2)
Knee	3 (1)	1 (–)	1 (–)	– (–)	– (–)	5 (1)
Foot	17 (3)	4 (–)	– (–)	4 (–)	– (–)	25 (3)
Ball	9 (–)	1 (1)	– (–)	1 (–)	– (–)	11 (1)
Surface	– (–)	2 (–)	– (–)	– (–)	1 (–)	3 (–)
Unknown	– (–)	– (–)	– (–)	– (–)	3 (1)	3 (1)
Total	109 (9)	42 (4)	25 (1)	12 (1)	4 (1)	192 (16)

Numbers in parentheses are number of injuries.

Head to head incidents

In 62 of the incidents (five injuries) the primary mechanism was head to head contact (fig 5). The point of impact on the injured player was the back of the head in 22 of the cases (35%), the face in 19 (31%), the side of the head in 15 (24%), and the forehead in 6 (10%). The relative horizontal speed of the players in the 62 head to head incidents was low in 44 cases (71%) and moderate in 16 cases (26%). The relative speed was high in only two of the head to head incidents.

The decision made by the referee was ''no foul'' in 44 cases (71%), and in 12 cases (20%) a free kick for the exposed player was awarded. None of the free kicks resulted in a yellow or red card. Of the five injuries there was one concussion, two contusions, and two lacerations, all of them minor.

Foot to head incidents

In 25 of the incidents (3 injuries) the primary mechanism was a kick to the head (fig 6). A ''high kick'' was the cause in 10 cases (40%), while the injured player had bent down in five incidents. The point of impact on the head was the face in 17 cases (68%), the forehead in four, and the back of the head in four cases.

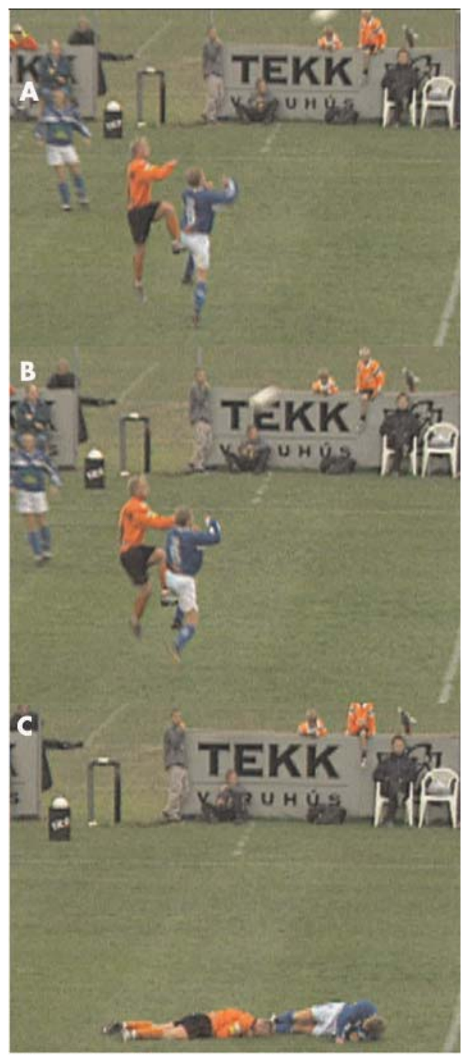

Figure 3 Elbow to head incident. (A) Close up just prior to impact. (B) Impact: the player in the orange shirt hits the opponent player on the side of the face with his elbow at shoulder level. (C) Both players down on the pitch just after the incident.

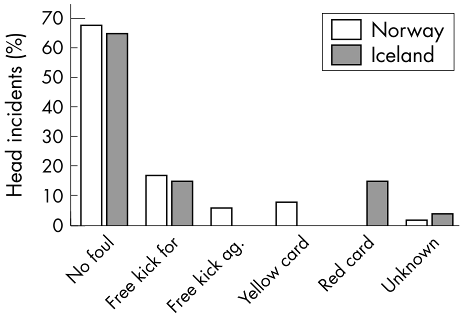

Figure 4 The referee's decision in incidents resulting from elbow, arm or hand to head contact in Norway (n = 53) and in Iceland (n = 26).

The referee's decision was "no foul" in 14 cases (56%), while a free kick for the exposed player was awarded in eight. Of the free kicks awarded, two resulted in a yellow card and one in a red card. Three injuries occurred from foot to head incidents: one nasal fracture, one mandibular fracture, and one contusion. Two injuries were classified as moderate and one as serious.

Goalkeeper incidents

In 20 (10%) of the incidents, the primary mechanism was involvement by the goalkeeper. Of these, the goalkeeper was the exposed player in nine cases, two of which resulted in an injury. The referee's decision was "no foul" in 15 (75%) of the incidents and in five cases a free kick for the exposed player was awarded. None of the free kicks resulted in either a yellow or a red card. Two injuries occurred, one concussion and one mandibular fracture; both were classified as serious.

DISCUSSION

The aim of this study was to analyse the mechanisms of head injuries in Norwegian and Icelandic elite football based on video tapes of match incidents. The main findings were that 58% of the incidents resulted from heading duels, and that 41% of the cases were impacts from the arm, elbow, or hand, while 33% were head to head impacts. Moreover, in the majority of the elbow incidents, the arm was at or above shoulder level and considered to be used actively or intentional in nearly all cases. Despite this, fouls were called in only one third of the cases.

Methodological considerations

When interpreting the results of the present study, some limitations must be borne in mind. Firstly, the diagnosis and grading of brain injury was based on reports by the team medical personnel. Under Scandinavian medical practice, diagnosis of brain injury is reserved for cases where a player suffers from loss of consciousness or retrograde amnesia. Diagnosing brain injury has always been a challenge for clinicians and to date there is no universal agreement on the standard definition or nature of concussion.[35 36] However, recently the first steps towards guidelines for the diagnosis and management of the athletes who suffer concussive injuries have been taken.[37] According to these guidelines, concussion may be caused either by a direct blow to the head or by a blow elsewhere on the body with an 'impulsive' force transmitted to the head, resulting in an immediate and short lived functional disturbance of neurological function and a graded set of clinical syndromes that may or may not involve loss of consciousness. This means that some of the facial fractures, lacerations, and even contusions to the neck in this study may also have lead to an unrecognised concussive injury. It is therefore reasonable to assume that concussive

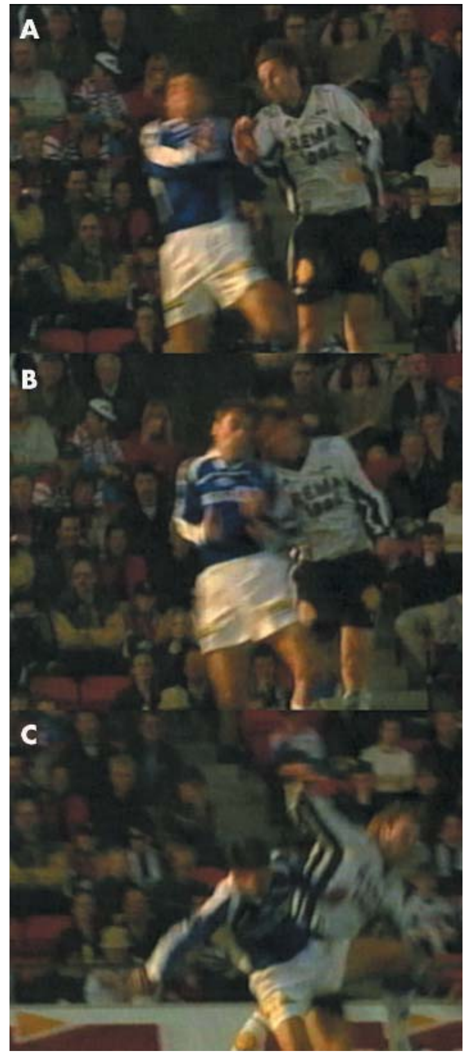

Figure 5 Head to head incident. (A) Close up just prior to impact. (B) Impact: the player in the white shirt hits the opponent on the side of the head with his forehead. (C) The moment just after impact.

injuries have been under-reported in the present study and that several more may be hidden among the head incidents that were not classified as time loss injuries. This can be verified from some of the video recordings where the player(s) appear to have sustained a mild brain injury, but an injury was not reported because the player either continued to play or practised as normal the following day. In a recent retrospective study by Delaney *et al*,[20] only about one in five football players realised that they had suffered a concussion. Our incidence of concussions therefore represents a minimum estimate; the true incidence of mild brain injury with transient cognitive impairment may be several times higher.

Secondly, the assessment of the videos was subjective and qualitative, and in some cases based on tapes with less than optimal quality and a limited number of available camera views. Nevertheless, the number of head incidents was relatively large, and the analysis revealed distinct patterns and detailed information on the mechanisms for head injuries in football. Furthermore, all but one of the head injuries reported by the medical staff were identified on video. Even keeping these limitations in mind, a systematic analysis of injury situations from video would seem to be the obvious approach towards a more detailed understanding of

Figure 6 Foot to head incident. (A) Close up just prior to impact. (B) Impact: the player in dark blue tries to kick the ball with a high kick, while the opponent player attempts to head the ball and is hit in the face by the foot. (C) Both players down on the pitch just after impact.

the mechanisms for sports injuries, providing more reliable information than retrospective player interviews.

Finally, it should be noted that the video recordings used in this study were from matches only. Therefore, only mechanisms for head injuries and incidents in match play could be evaluated. However, previous studies[23–25 27 33 38 39] have shown that most football injuries in elite players occur during match play, as was the case in the present study (data not shown). Whether the mechanisms for training and match injuries differ is unknown, although we would expect there to be fewer elbow to head and foot to head incidents and less foul play during training than in match play. In addition, there may be differences in injury mechanisms between elite male football players and other player populations (younger players, female players) that warrant attention in future studies.

Injury mechanisms

A number of studies show that selected groups of football players display some degree of cognitive dysfunction.[5 8–11] However, whether the culprit is purposeful heading[10 11] or acute head injuries (including repeated, relatively mild concussions)[8] is not yet established. To further understand the relationship between heading, head injury, and cognitive deficits, it is important to learn more about head impacts during the football—that is, actual impacts of a ball on the head, exposure to heading at different competitive levels and age groups, and concussive injury rates.[1] It is also necessary to conduct longitudinal studies focusing on exposure to heading, head injury, and cognition, as well as potential confounding factors such as alcohol and drug consumption and head injuries outside football.[40] Furthermore, the specific mechanisms for head incidents and injuries in football need to be described in detail in order to establish targeted preventive measures.

The present video analysis clearly shows that the primary mechanism of head injury during matches in elite football is a contact mechanism between two opposing players occurring in a heading duel, rather than purposeful headings. In addition, the mechanism most often involves arm to head or head to head contact. This result contrasts somewhat with a prospective study on collegiate men and women, in which head to head contact dominated.[19] Barnes *et al*[41] and others[42] described head to ground and head to goalpost as the main mechanisms for head injuries in football, whereas we found that these mechanisms are infrequent. Furthermore, situations where the players are hit in their head by the ball are also rare.

The present study showed a difference between the location and mode of impact. In head to head incidents, the location of impact was most commonly the side or the back of the head, whereas for elbow, arm, or hand to head incidents, foot to head incidents, and ball to head incidents, the face was the location most prone to impact. Moreover, impact to the forehead resulted in very few incidents regardless of the mode of impact. As discussed below, these findings are important when considering the potential of preventive headgear.

Elbow, arm, and hand contact to the head was the most common mechanism observed (fig 7). This is in contrast with findings from English professional football, showing that only in 1% of the match injuries was use of the elbow the injury mechanism.[22] Furthermore, in most of the cases we observed, the elbow was used actively at or above shoulder level, possibly to fend off the opponent and get in position to head the ball. Additionally, even if relatively few in number, the foot to head incidents have the potential of causing severe injuries to the face and head. This study demonstrates that almost half of the foot to head incidents were ''high kicks'', where the point of impact was the face in the majority of the cases.

When comparing the results from Norway and Iceland, there are some differences in the frequency of head injuries and incidents. Fever head incidents occurred in Iceland, and the ratio of injuries to incidents was twice as high. We have no explanation for this. However, the detailed analyses of each incident and injury situation revealed no difference in the injury mechanisms between the two countries (see figs 1–3). This is significant, as it suggests that the results may be valid for club soccer more in general, and not just a result of a particular style of play in one country.

Prevention of head injuries

Head incidents accounted for 27% of the total number of incidents and 6% of the injuries in the present study. Next to tackling duels, heading duels cause most incidents and injuries in professional football, both in the defending and attacking playing phases.[43] Although it should be acknowledged that this is in contrast to the figures from English professional football, which show that only 1% of the competition injuries occurred in heading duels,[22] the present

Figure 7 Typical injury mechanism. Elbow to head contact in a heading duel. The player in the blue shirt uses his right elbow actively above shoulder level to prevent the opponent player from reaching the ball.

data suggest that priority should be given to preventing head injuries.

In response to the concern that participation in football can lead to brain impairment, several manufacturers have developed headgear for football. Among North American youth football players, helmets and headbands have been used, but one experimental test of headbands showed little ability to attenuate the impact while heading a football ball.[13] The present study shows that purposeful heading of the ball was not a cause of incidents and injuries. Moreover, in the majority of the cases, the point of impact was the face, and it is highly unlikely that headgear devices would be able to prevent these injuries.

Based on the current results, the most promising strategy to reduce head injury risk would appear to be discouraging elbow and arm use in heading duels. Although some of the elbow to head incidents led to free kicks, and a few of these even to a yellow or red card, in nearly 70% of these incidents the decision made by the referee was no foul. Our analysis also showed that 20% of the elbow to head incidents involved what appeared to be intentional strikes with the arm or elbow. Elbow use in football has been a focus among referees for some time, but this focus has mainly been directed at playing situations where the elbow or arm/hand is used intentionally and hence recognised to be a result of unfair playing. This may explain why so few of these cases were called as foul play.

Based on this, the obvious proposals to prevent head injuries are to ban the use of elbows at or above shoulder level in heading duels and to focus on stricter enforcement of the laws of the game in relation to elbow use when challenging for ball possession. This may possibly contribute to a reduction in the number of potentially dangerous elbow to head incidents in football. However, the game of football is highly competitive, and at the highest professional level, the glory and financial benefits of winning are considerable. It may therefore be tempting for players to make use of all means, including intentional fouls, to succeed. This development needs to be taken seriously and the approach to require the referees to be stricter in their implementation of the existing laws of the game may prove not to be sufficient. A 10 minute suspension for active "high elbowing" and "high kicking" (which may cause high impact serious injuries), similar to the existing rules of some other sports such as ice hockey and team handball, may be an improvement of the football rules that could possibly contribute to reduce aggressiveness in matches.

WHAT IS ALREADY KNOWN ON THIS TOPIC

- Purposeful heading is an important part of the game of football.
- Head injuries occur as a result of impact to the head or face and heading alone does not seem to cause brain injury.
- The main mechanisms for head injuries based on retrospective player interviews have previously been assumed to be head to head contact.

WHAT THIS STUDY ADDS

- A thorough video analysis reveals that heading duels are common in football and that many of these lead to situations with a high risk of injury.
- The two most frequent head incident mechanisms in elite football were elbow to head and head to head contact in heading duels.
- More than 40% of the head incidents are caused by impact by elbow, arm or hand.
- In the majority of the elbow to head incidents, the elbow was used actively or intentionally at or above shoulder level.
- Although the arm was used actively in 77% of these cases, no foul was usually called.
- Stricter enforcement of the rules of the game or rule changes concerning elbow use may be considered to reduce the risk of head injury in football.

CONCLUSIONS

This study shows that video analysis can be used to provide detailed information about the mechanisms for head injuries in football. The two most frequent injury mechanisms were elbow to head and head to head contacts in heading duels. In the majority of the elbow to head incidents, the elbow was used actively or intentionally at or above shoulder level. The face is the main point of impact in head incidents in elite and professional football. Stricter rule enforcement or even changes in the laws of the game concerning elbow use may be considered to reduce the risk of head injury in football.

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