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Injury surveillance and prevention in male professional football

Dissertation for the Degree of PhD 2014

FACULTY OF MEDICINE
UNIVERSITY OF OSLO

ISBN 978-82-8264-837-0
No. 1939

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Oslo Sports Trauma
RESEARCH CENTER

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Series of dissertations submitted to the
Faculty of Medicine, University of Oslo
No. 1939

ISBN 978-82-8264-837-0

Cover: Inger Sandved Anfinsen.
Printed in Norway: AIT Oslo AS.

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Acknowledgements

I have been lucky! I have been given the possibility to work with this thesis at the Oslo Sports Trauma Research Center (OSTRC), Department of Sport Medicine, Norwegian School of Sports Sciences (NIH). I will be forever grateful for this opportunity, and for all the support and help I have received from day one. I can't think of a better workplace than NIH!

Thor Einar Andersen, my supervisor, you have been the cornerstone for me during these 7 years at NIH. I appreciate the combination of a great researcher and a great person. In addition to the knowledge you possess in the field of sport sciences, I would like to emphasize your personal qualities. Your door has always been open, and it has been great to experience your knowledge about research, football, life in general and Solskjær songs. Thank you!

Roald Bahr, your achievements in the world of sports sciences are second to none. You have set the "Bahr" in the way you work; thorough and effective. It has been inspiring to suffer from your "epistaxis moments" (proofreading) when reading applications and manuscripts.

Lars Engebretsen, I thank you for giving me the opportunity to start at the Medical Student Research Program and OSTRC. Together with Roald, you have built a world leading center, not only in terms of high research quality, but also socially. I will be forever grateful.

Ingar Holme, the best statistician in the field of sports medicine, a statistical oracle, for always answering statistical questions in the simplest way. In periods I have bombarded you with questions and challenges, but you always have a solution.

Bjørge Herman Hansen, PhD, for being who you are, a down-to-earth teddy bear from Kristiansand who always seem to be in high spirits, but also being a good partner in crime (practical jokes) and sometimes exercise.

Torbjørn Soligard, PhD, you helped me settle in the "bomb room" at NIH. I have enjoyed our common sense of humor and banter. Our stimulating discussions on football, life and research have made working on this thesis more enjoyable. I am also grateful for your help with data collection, together with Eirik Kristianslund, Roger Olsen and Tonje W. Flørenes.

Eirik Kristianslund, Agnethe Nilstad and Kathrin Steffen, your constructive feedback on my manuscripts, as well as discussions about football medicine have been invaluable. Elin Kolle, I really appreciate our friendship, it is always enjoyable to take the metro together with you to work. I would also like to thank you for all the SPSS and statistical help you have offered me over these years. Tron Krosshaug, I am very sorry that I have shown a severe lack of compliance to the strength training regime you have tried to introduce to me. Truls Straume-Nesheim and Jostein Steene-Johannessen, thank you for letting me be the star in your interpretation of the "Nativity of Jesus". Cathrine Nørstad, sharing office with you has been a pleasure. Julie Stang, your positive personality is admirable, it is impossible to be in a bad mood around you. Sigmund Andersen, a great leader and boss, you have the ability to see everyone, a skill much appreciated.

I would also like to thank all colleagues and friends at the Department of Sports Medicine and Sciences and OSTRC for being including and positive, and creating such a good working environment. I have really enjoyed working with every single one of you. I have loved the down to earth environment, including the wine lottery every Friday and the frequency of cakes in the lunch ☺

I would also thank all the participating clubs, contact persons, coaches, players participating in the different projects; this thesis couldn't have been done without you.

Jarle Breivik, Else-Marie Siebke and Lise Sofie Haug Nissen-Meyer at the Medical Student Research Program of the University of Oslo for making it possible to combine research and medical school. You create a platform for a young researcher.

I would also like to thank my family and friends for always being supportive and helping out when needed. Finally, I would like to thank my girlfriend Helene for your full support, for being patient and giving me valuable feedback on my spelling, grammar and my illogical chain of thoughts.

List of Papers

This dissertation is based on the following original research papers, which are referred to in the text by their Roman numerals:

I. Bjørneboe, J., Flørenes, T. W., Bahr, R., Andersen, T. E. Injury surveillance in male professional football; is medical staff reporting complete and accurate? Scand.J.Med.Sci.Sports. 2011. 21, 713-720.

II. Bjørneboe,J., Bahr,R., and Andersen,T.E. Gradual increase in risk of match injury in Norwegian male professional football - a six-year prospective study. Scand. J. Med. Sci. Sports. 2012. [Epub ahead of print]

III. Bjørneboe, J., Bahr, R., Andersen, T. E. Risk of injury on third-generation artificial turf in Norwegian professional football. Br.J.Sports Med. 2010. 44, 794-798.

IV. Bjørneboe, J., Bahr, R., Andersen, T. E. Video analysis of situations with a high-risk for injury in Norwegian male professional football; a comparison between 2000 and 2010. Br.J.Sports Med. 2013a. [Epub ahead of print]

V. Bjørneboe, J., Bahr, R., Dvorak, J., Andersen, T. E. Lower incidence of arm-to-head contact incidents with stricter interpretation of the Laws of the Game in Norwegian male professional football. Br.J.Sports Med. 2013b. 47, 508-514.

Abbreviations

ACL	Anterior Cruciate Ligament
AT	Artificial Turf
CI	Confidence Interval
CISIR	Canadian Intercollegiate Sports Injury Registry
GEE	Generalized Estimating Equations
EC	European Championship
FA	Football Association
FIFA	Fédération Internationale de Football Association
F-MARC	FIFA Medical Assessment and Research Center
MCL	Medial Collateral Ligament
MRI	Magnetic Resonance Imaging
NCAA	National Collegiate Athletic Association
NG	Natural Grass
NH	Nordic Hamstrings
OA	Osteoarthritis
OSTRC	Oslo Sports Trauma Research Center
RCT	Randomized Controlled Trial
RR	Rate Ratio
WC	World Cup

Summary

Football is one of the most popular sports both in Norway and worldwide. Studies have shown that the injury incidence in football matches is approximately 1000 times higher than industrial occupations such as construction and mining.

The overall aim of this thesis was to reduce the risk of injuries in Norwegian male professional football, and the studies are based on a prospective injury surveillance system established in 2000 in the Norwegian male professional league by the Oslo Sports Trauma Research Center (OSTRC). The aim of Paper I was to assess the accuracy of the routine injury surveillance system as performed by medical staff. We compared two different injury recording methods (medical staff registration vs. player interviews) from July through October 2007. In Paper II we monitored the risk of injury in Norwegian professional football, and reported on the injury incidence and injury pattern from 2002 through 2007. In Paper III, we evaluated the risk of injury on artificial turf compared to natural grass from 2004 through 2007. In Papers IV and V, we conducted a video analysis of situations with a high propensity for injury. An incident was recorded if the match was interrupted by the referee, and the player lay down on the pitch for more than 15 s, and appeared to be in pain or received medical treatment. In Paper IV, we compared the incidence of incidents during the 2000 season to the 2010 season. Subsequently, in Paper V, we assessed whether a stricter interpretation of the Laws of the Game, with red cards for high elbows in heading duels and for late/two-foot tackles, could reduce the potential for injuries. A pre-/post-intervention design was utilized, where the rate of incidents and injuries from the 2010 season (pre) was compared to the 2011 season (post).

In the validation of the injury surveillance system, we found that 51% of all injuries were reported by both methods, 30% by medical staff registration only and 19% by player interviews only. For injuries captured by both recording methods, the agreement was very good for the categories body part injured, activity when injured and injury type, and good for severity (Paper I).

During the six-season observation period (Paper III) the incidence of acute injuries was 15.9/1000 player-match hours (95% confidence interval (CI): 14.9-16.8), 1.9/1000 player-training hours (95% CI: 1.7-2.0) and 1.4 (95% CI: 1.3-1.5) overuse injuries/1000 player hours of activity. A linear regression model showed an increase of 1.06 acute match injuries/1000 player-match hours (95% CI: 0.40-1.73) per year, corresponding to a total increase of 49% during the six-year study period. When accounting for interteam variation and clustering effects using a Generalized Estimating Equations (GEE) model, the increase in injury incidence was attenuated (0.92

injuries/1000 player-match hours 95% CI: -0.11-1.95, p=0.083). We did not detect any change in the incidence of overuse injuries (p=0.73), nor in acute training injuries (p=0.49) during the six-year study period.

In Paper III we did not detect any difference in the injury incidence during matches (rate ratio (RR): 1.04, 95% CI: 0.86 to 1.25) or training (RR: 1.07, 95% CI: 0.87 to 1.32) between artificial turf and natural grass, nor in injury location, type or severity between turf types.

In Paper IV we found a rate of incidents of 74.4/1000 player-match hours (95% CI: 67.3 to 81.5) in the 2000 season and 109.6 (95% CI: 102.3 to 116.9) in the 2010 season, an increase from 2000 to 2010 (RR: 1.47, 95% CI: 1.31 to 1.66). We observed a significantly higher rate of opponent-to-player contact and non-contact incidents in the 2010 season. We found no change in the awarding of yellow or red cards between the two seasons.

Paper V showed that the rate of contact incidents was 92.7 (95% CI: 86.0 to 99.4) in the 2010 season and 86.6 (95% CI: 80.3 to 99.4) in the 2011 season, with no difference between the two seasons. We found, however, a reduction in the incidence of head incidents (RR): 0.81, 95% CI: 0.67 to 0.99), and head incidents caused by arm-to-head contact (RR: 0.72, 95% CI: 0.54 to 0.97). We found no difference in tackling characteristics or injury rate caused by player-to-player contact.

Conclusions

Prospective injury surveillance by team medical staff in Norwegian male professional football underestimates the incidence of time-loss injuries by at least one-fifth. The six-season injury registration documented that the overall incidence of acute match injuries in Norwegian male professional football increased by 6 % per year during the study period, although this increase was not consistent across teams. No significant differences were detected in injury rate or pattern between third-generation artificial turf and natural grass in Norwegian male professional football. We found an increased rate of non-contact and opponent-to-player contact incidents in both heading and tackling duels with a high injury potential in the 2010 season compared to ten years earlier, even if there was no increase in the frequency of duels. We found no significant differences in the overall rate of incidents after the introduction of stricter rule enforcement. However, the rate of head incidents and arm-to-head incidents was reduced.

Introduction

Football is one of the most popular team sports in the world. FIFA (Fédération Internationale de Football Association) has 208 member associations and about 240 million participating football players. The Football Association of Norway (NFF) consists of 1 933 clubs, which organizes 27 532 teams, 364 940 players of which 105 595 female players; which makes it the biggest sports federation in Norway (Haavik, 2013).

Laws of the Game

The modern game of European football was established in England with the foundation of the Football Association in 1863. It was decided that a game of football should be played between two teams with 11 players on each side. A goal was scored when the ball was kicked into a goal placed on each side of the pitch. Another important feature of the first rules of football, which was also an important injury prevention measure, was to ban kicking other players' legs. The sanction was to give the ball to the team of the offended player.

Football rules are divided into seventeen categories, and are called the Laws of the Game. They are governed by the International Football Association Board (IFAB). The Board meets once a year to discuss possible rule changes. Laws 5 and 6 include descriptions on how the referee and his assistants should enforce the Laws of the Game; in addition, Law 12 deals with fouls and misconducts. These three rules are the main rules with potential implications for the risk of injury (FIFA, 2011). Until recently, the Laws of the Game have provided given little guidance about how referees and match officials can contribute to injury prevention.

If the referees consider a challenge to be foul play, two disciplinary sanctions can be awarded. A player is cautioned (awarded a yellow card) if the challenge is regarded as "careless" (i.e. the player has shown a complete disregard to the danger to, or consequences for, his opponent). If the challenge is deemed as "using excessive force" (i.e. the player has far exceeded the necessary use of force and is in danger of injuring his opponent), the player is sent off (awarded a red card) (FIFA, 2011).

Injury prevention models

In 1992, van Mechelen introduced a four-step model for injury prevention research. Firstly, the extent of the injury problem has to be established, through a description of injury incidence and severity. Secondly, one has to identify the injury etiology, the risk factors and mechanisms for injury. The first two steps are mainly described employing prospective cohort studies (Bahr and Holme, 2003). Based upon the results from steps one and two, a potential preventive measure may be identified and introduced. Finally, as the fourth step, the efficacy of the preventive measure should be assessed, either by repeating the first step or ideally through a randomized controlled trial. Effective injury prevention studies are not necessarily easily implemented in daily life; therefore, Finch et al. (2006) expanded the four-stage sequence with two more steps emphasizing the need for implementation to ensure that preventive measures are widely adopted (Table 1).

Table 1. The Translating Research into Injury Prevention Practice framework for research leading to real-world sports injury prevention (Finch, 2006)

TRIPP Stage	Research need	Research process
1	Count and describe injuries	Injury surveillance
2	Understand why injuries occur	Prospective studies to establish etiology and mechanisms of injury
3	Develop "potential" preventive measures	Basic mechanistic and clinical studies to identify what could be done to prevent injuries
4	Understand what works under "ideal" conditions	Efficacy studies to determine what works in a controlled setting (e.g. RCT's)
5	Understand the intervention implementation context including personal, environmental, societal and sports delivery factors that may enhance	Ecological studies to understand implementation context
6	Understand what works in the "real world"	Effectiveness studies in context of real-world sports delivery (ideally in natural, uncontrolled settings)

Klügl et al. (2010) analyzed 11 859 articles on sports injury prevention, and classified them according to the TRIPP framework. They found that only 44% of the papers were original research articles. Another finding was that only 11% of the articles (n=1362) reported preventive measures; of these 33% reported on their efficacy (how the intervention works in a clinical trial) (n=460), 12% were implementation studies (n=162), and only 3% were effectiveness studies (how the intervention works in practice) (n=32). Thus, only 1% of all studies on sports injury prevention have evaluated implementation and effectiveness in an implementation context (Klugl et al., 2010). In addition, they found that studies on rules and regulations constituted only 0.6% (n=63) of the 11 859 articles retrieved, despite some of these studies showing considerable effects.

Injury definition

The risk of injury in sports has been evaluated for decades. The definition of what constitutes an injury has spanned from reporting physical complaints by players (Junge et al., 2004a) to hospital visits (Hoy et al., 1992) and insurance claims (Roaas and Nilsson, 1979), leading to diversity in both the overall injury risk and injury patterns, making it difficult to compare findings from different studies.

In 2006, F-MARC hosted a group of experts involved in the study of football injuries. The result was a consensus statement that aimed at establishing definitions and methodology, implementation and reporting standards for studies of injuries in football (Fuller et al., 2006). The consensus statement defines an injury as "any physical complaint sustained by a player that results from a football match or football training", irrespective of the need of medical attention or time loss from football activity. An injury that results in a player being unable to take a full part in future football training or match is referred to as a "time-loss" injury, an injury that results in a player receiving medical attention is referred to as a "medical-attention" injury (Fuller et al., 2006).

All injury definitions have certain limitations and advantages that need to be acknowledged. The "time-loss" definition is highly dependent upon training frequency; thus, minor injuries can easily be missed when activity is not daily, which might be the case at the amateur and youth level. In addition, the "time-loss" definition is sports-specific; a football player might play with a broken finger, whereas a volleyball player might be prevented from participation. Minor injuries, as blisters and abrasions, are likely to be missed using a "time-loss" definition, but will be captured by the "physical-complaint" definition. Access to medical staff, importance of the match and frequency of activity might influence the timing of return to full football activity and therefore the length of absence with a "time-loss" definition. A "medical staff" definition is highly dependent on access to health care, and therefore not tailored for youth and amateur football. In other words, the rate of injury reported in a study is dependent upon the definition, as players will not always miss training or seek medical assistance because of a physical complaint. It can therefore be expected that a "physical complaint" definition will yield a higher injury rate than a "medical-attention" definition, and "time-loss" definition will result in the lowest registered injury rate (Bahr, 2009).

Another important part of injury registration is the recording of severity. Several different definitions have been used over the years: nature and duration of injury, sporting time lost, working time lost, the presence of permanent sequelae, type of treatment or costs (van Mechelen et al., 1992). The most commonly used severity definition in the field of sports injury research has been the number of days of absence from activity. The National Athletic Injury Registration System (NAIRS) classified injuries as minor (1-7 days), moderate (8-21 days) and severe (>21 days) (van Mechelen et al., 1992). The FIFA consensus statement categorized injury severity into slight (0 days), minimal (1-3 days), mild (4-7 days), moderate (8-28 days) and severe (>28 days) (Fuller et al., 2006).

Injuries have commonly been separated into two groups; acute and overuse injuries. An acute injury has been defined as an injury resulting from a specific, identifiable event and an overuse injury as one caused by repeated microtrauma without a single, identifiable event responsible for the injury (Fuller et al., 2006). Others have defined overuse injuries as injuries with an insidious onset with a gradually increasing intensity of discomfort without an obvious trauma (Arnason et al., 2004a). However, it has been argued that a time-loss definition is not suitable for the reporting of overuse injuries (Bahr, 2009). Overuse injuries are due to repetitive low-grade forces beyond the tolerance of the tissues, which in most cases repair without verifiable clinical symptoms (Bahr, 2009). Nevertheless, if the process exceeds the tissues inherent ability to repair and adapt, it might result in a noticeable overuse injury with corresponding symptoms and absence from activity, thus, captured through a time-loss definition.

The risk of injury has generally been expressed as incidence, which is defined as the number of new cases of an injury in a defined population in the course of a given time period. Injury incidence is commonly reported as the number of injuries per 1000 player hours of exposure to football.

Injury registration methods

Few continuous surveillance systems have been established in the world of sports. The NCAA injury surveillance system was established 30 years ago, and is the largest ongoing athletic injury database in the world (Dick et al., 2009). It monitors formal team activities, numbers of participants, and time-loss injuries from the first day of formal preseason practice to the final postseason contest for 16 collegiate sports. A similar system is the Canadian Intercollegiate Sports Injury Registry (CISIR) (Meeuwisse and Love, 1998). In order to make ice hockey safer the International Ice Hockey Federation (IIHF) established an injury surveillance system in 1998, where team physicians collect injury information after each match during championships (International Ice Hockey Federation, 2011). The International Olympic Committee (IOC) has also developed an injury surveillance system, practical for both individual and team sport and for events with one sport and several sports (Junge et al., 2008). Similar reporting systems have been established for several seasons or tournaments in skiing and snowboarding (Flørenes et al., 2011), rugby (Bathgate et al., 2002; Best et al., 2005), team handball (Langevoort et al., 2007), cricket (Orchard et al., 2005) and athletics (Alonso et al., 2009).

The first continuous injury surveillance system in football was implemented during the World Cup in France in 1998 (Junge et al., 2004b). The same methods are now in use in all FIFA tournaments, male and female. The medical staff of each country registers medical reports on a daily basis, and the medical forms are collected by a FIFA medical officer after each match. UEFA has taken a similar approach (Hägglund et al., 2005a). Prospective registration from club football over more than one season have been conducted in Norway, England, Sweden and in the Champions League (Hawkins and Fuller, 1999; Hägglund et al., 2006; Andersen et al., 2004d; Ekstrand et al., 2011c; Eirale et al., 2013a).

Injury incidence is not only dependent on the injury definition, but the registration method used will also have a significant impact on the injury incidence reported (Inklaar, 1994a; Dvorak and Junge, 2000; Fuller et al., 2006). Over the last four decades, many different methods have been used to record injuries in sports, leading to a substantial discrepancy in the injury incidences reported (Fuller et al., 2006; Clarsen et al., 2012; Bahr, 2009).

Previous studies from football, among preschool children and physical education students have shown that more injuries are recorded by prospective injury registration compared to retrospective interviews (Junge and Dvorak, 2000; Twellaar et al., 1996; Fonseca et al., 2002). Prospective injury registration is not complete, but the reliability of retrospective injury registration is poorer (Twellaar et al., 1996). Czech football clubs were followed on a weekly basis by a physician who recorded injuries sustained by their players. In addition, the players filled out a questionnaire after the 12-month season self-reporting injuries they had sustained (Junge and Dvorak, 2000). The study group found that there was significant recall bias associated with retrospective player interviews, especially regarding mild injuries sustained close to one year prior to the interviews (Junge and Dvorak, 2000). The localization and circumstances of injury were similar in both the prospective and retrospective data collection (Junge and Dvorak, 2000).

The consensus statement on injury definitions and data collection procedures for studies of injuries in football emphasized that injury registration should be done prospectively, and conducted by a member of the medical staff (Fuller et al., 2006). Nevertheless, medical staff recording is not necessarily the best injury registration method in all settings. A study among elite alpine skiers and snowboarders found that only 61% of all recorded injuries were reported by the medical staff, and that only 6% of the injuries recorded by the medical staff were missed by retrospective player interviews (Flørenes et al., 2011). In addition, in sports were the athletes do not have a close follow-up from the medical staff, medical staff reporting could lead to a substantial underreporting of injuries. Nilstad et al. (2012) found that medical staff reporting missed approximately 2/3 of all injuries, and 50% of all severe injuries compared to individual self-reported registration through text messaging in female elite football. Thus, injury recording systems ought to be tailored, not only the sport, but also the level of play and other factors potentially influencing the injury recording system.

In addition to the injury registration, recording of exposure is essential for studies evaluating injury incidence. Exposure registration in football can either be recorded on a team basis or individually. Team-based exposure registration is typically conducted by multiplying the hours of training session or match play with the number of participating players. In contrast, individual exposure registration allows for the fact that exposure to match play and training can vary between players in the same team. Individual exposure registration would allow the study group to control player attendance versus injury reports received, and should serve to increase the capture rate (Fuller et al., 2006; Hägglund et al., 2005a).

The quality of the results based on an epidemiological study is dependent on the accuracy and reproducibility of the information collected. To interpret results from injury registration it is important to know the validity and reliability of the injury registration system. However, it is not known whether a routine injury surveillance system captures all time-loss injuries suffered by players. This question was therefore addressed in Paper I.

Injury risk in male football

Injury incidence

As a result of the combination of high participation rates in football and the risk of injury, football is responsible for between one-fourth and one-half of all sports-related injuries in Europe (Keller et al., 1987; Hoy et al., 1992; Inklaar et al., 1996; Bahr et al., 2003). To examine the injury incidence a literature search on PubMed was conducted using the following search terms: (injury or injuries) and incidence and (football or soccer) and (male or adult) and epidemiology and prospective. The reference lists of retrieved articles were checked manually for other potentially relevant studies. Table 2 summarizes the injury incidences from studies on adult male football at both the club and national team level.

Nineteen studies have reported the rate of injury among adult male footballers playing at the club level. All studies were prospective, and included injury registration from more than one club, and for at least half a season. These studies have shown that the injury incidence in football is high; between 65% and 82% of the players will sustain at least one injury during a season (Arnason et al., 2004a; Nielsen and Yde, 1989). In a recent study by Ekstrand et al. (2011c) each player at the highest professional level on average sustained two injuries per season. Drawer and Fuller (2002) have demonstrated that the injury incidence during matches is approximately 1000 times higher than high-risk industrial occupations (i.e. construction and mining).

Studies have shown that there is a significantly higher incidence of injury during match play compared to training. The injury incidence has been reported to range between 1.8 and 11.8 injuries per 1000 player-training hours, while the match injury incidence in adult male football ranges from 11.3 and 35.3 injuries per 1000 player-match hours (Table 2).

From studies at the elite level, using a time-loss definition, the training injury incidence is reported to range from 1.9 to 11.8 per 1000 player-training hours and the incidence of time-loss match injuries ranges from 13.0 to 34.8 per 1000 player-match hours (Table 2).

Recent studies have found that on a team level, a low incidence of injuries and high match availability were associated with better team performance (Hägglund et al., 2013; Eirale et al., 2013b; Arnason et al., 2004a).

The risk of injury at the senior national team level is slightly higher compared to the club level. The injury rate varies between 40 and 51 injuries per 1000 player-match hours during European Championships, World Cup and Olympic Games matches (Table 2).

Few studies have been carried out over several consecutive seasons in order to monitor changes in injury incidence and injury circumstances and injury pattern over time. Therefore, to monitor the incidence of injury and injury pattern in Norwegian male professional football over time, a continuous injury registration system was established in 2000. The results from six consecutive seasons are presented in Paper II.

Table 2. Summary of injury incidence and injury characteristics in prospective studies of male adult football players at club level

Reference	Hägglund (2003)	Ekstrand & Gillquist (1983)	Nielsen & Yde (1989)	Poulsen (1991)	Engstrøm (1990)	Arnason (1996)	Lüthje (2007)	Hawkins & Fuller (1999)	Hawkins (2001)	Morgan (2001)	Arnason (2004)
Country	Sweden	Sweden	Denmark	Denmark	Sweden	Iceland	Finland	England	England	USA	Iceland
Study period	1982	1980	1986	1986	-	1991	1993	1994-97	97-99	1996	1999
Level of play	Elite	Amateur	Amateur	Elite/amateur	Elite	Elite	Elite	Professional	Professional	Professional	Elite
Injury definition	Time-loss*	Time-loss*	Time-loss*	Time-loss*	Time-loss*	Time-loss*	Medical attention	Time-loss^	Time-loss+	Medical attention	Time-loss*
No of injuries	236	256	109	57	85	85	317	578	6030	399	244
Players injured (%)	76	69	82	-	75	71	65	-	-	-	56
Acute injuries (%)	-	69	66	65	65	91	92	95	-	-	84
Overuse injuries (%)	-	31	34	35	35	9	8	5	-	-	16
Re-injury	-	-	42	-	-	35		22	7	-	
Injury incidence											
Match	20.6	16.9	14.3	20.3	13	34.8	11.3	25.9	-	35.3	24.6
Contact (%)		59%	-	-	-	44%		49%	-		-
Training	4.6	7.6	3.6	4.5	3.0	5.9	1.8	3.4	-	2.9	2.1
Severity											
Minor	68	62	46	-	27	-		52	33	60	38
Severe	9	11	35	-	34	-		11	23	14	23[A]
Injury location											
Head/neck	-	-	-	4	-	-	9	2	7	-	3
Upper limb	-	-	-	2	-	-	6	3	3	-	6
Trunk	-	5	-	2	2	-	9	8	3	-	7
Lower limb	-	88	84	93	93	82	76	88	87	77	83
Hip/groin	-	13	22	19	12	-	2	13	12	11	13
Thigh	-	14		18	8	-	22	23	23	10	24
Knee	-	20	18	23	33	-	19	15	17	21	16
Lower leg	-	12	-	2	11	-	8	14	13	-	13
Ankle	-	17	36	19	22	-	17	17	17	18	9
Foot	-	12	8	21	7	-	8	6	6	-	5
Injury type											
Joint & lig.	-	31	48	42	36	22	-	20	25	-	18
Muscle & tend.	-	41	37	30	45	29	-	42	42	21	31
Contusion	-	20	9	12	13	20	32	18	13	-	21
Fracture	-	4	6	7	4	-	7	4	4	-	-
Concussion	-	-				-	1	-		-	.

**One training session or match; ^the day after the injury; +>48 hour; A>21 days; AT- athletic trainer*

Table 2. Summary of injury incidence and injury characteristics in prospective studies of male adult football players at club level

Reference	Andersen (2004)	Hägglund (2003)	Hägglund (2005)		Waldèn (2005)		Waldèn (2005)	Hägglund (2006)	Hägglund (2009)	Engebretsen (2008)	Ekstrand (2011)
Country	Norway	Sweden	Denmark	Sweden	Sweden		Sweden	Sweden	Sweden	Norway	CL
Study period	2000		2001		2001		2002	2002	2005	2004	2001-08
Level of play	Professional	Professional	Professional		Professional		Professional	Professional	Professional	Amateur	Professional
Injury definition	Time-loss^	Time-loss*	Time-loss*		Tissue injuries	Time-loss*	Time-loss*	Time-loss*	Time-loss*	Time-loss*	Time-loss*
No of injuries	121	715	395	481	765	715	658	1189	548	505	4483
Players inj. (%)	-	77	81	67	77	77	85	76	79	56	-
Acute (%)	-	-	61	63	65	63	63	62	-	70	72
Overuse (%)	-	-	39	37	35	37	27	38	-	30	28
Re-injury	-	-	30	24		22	15	-	19	-	12
Injury incidence											
Match	21.5	25.9	28.2	26.0	27.2	25.9	30.5	27.2	28.1	12.1	27.5
Contact (%)						-			-	52	-
Training	-	5.2	11.8	5.0	5.7	5.2	5.8	5.7	4.7	2.7	4.1
Severity											
Minor	44	60	67	60	-	60	56	61	65	43	48
Severe	26^A	9	12	9	-	9	15	11	9	16	16
Injury location											
Head/neck	-	-	-	3	-	2	3	3	2		2
Upper limb	-	-	-	2	-	-	-	2	3		4
Trunk	-	-	7	7	-	6	6	8	8		7
Lower limb	75	-	89	87	-	88	86	87	88	-	87
Hip/groin	-	-	15	16	-	16	12	17	18	12	14
Thigh	-	-	22	23	-	23	23	23	23	15^H	24
Knee	-	-	21	15	-	16	20	17	16	12	18
Lower leg	-	-	11	16	-	15	11	13	10	-	11
Ankle	-	-	13	10	-	10	14	10	14	11	14
Foot	-	-	7	7	-	8	6	7	7	-	6
Injury type											
Joint & lig.	-	-	23	16	-	17	24	17	18	-	18
Muscle & tend.	-	-	21	26	-	22	26	-	44	-	42
Contusion	-	-	14	17	-	17	16	15	18	-	17
Fracture	-	-	2	2	-	3	-	3	3	-	4
Concussion	-	-	-	-	-	-	-	-	1	-	-

**One training session or match; ^the day after the injury; [H] Reported only hamstring injuries; CL = Champions League*

Table 2. Summary of injury incidence and injury characteristics in prospective studies of male adult football players at national team level

Reference	Ekstrand (2004)	Junge (2004)	Yoon (2004)		Junge (2004)	Junge (2004)	Junge (2006)	Waldèn (2007)	Dvorak (2007)		Hägglund (2009)	Dvorak (2011)	
Tournament	NT	WC	Asian Cup		Olympics	WC	Olympics	EC	World Cup		EC	World Cup	
Study period	1991-97	1998	2000		2000	2002	2004	2004	2006		2008	2010	
Injury definition	Time-loss*	Physical complaint	Physical complaint	Time-loss	Physical complaint	Physical complaint	Physical complaint	Time-loss*	Physical complaint	Time-loss^	Time-loss*	Physical complaint	Time-loss^
No of inj.	71	149	133	47	116	171	77	45	145(45.9^{TL})	97	56	229	144
Players inj. (%)	-	-	-	-	-	-	-	11	-	-	14	-	-
Acute (%)	80	-	-	-	-	-	-	80	-	-	73	-	-
Overuse (%)	20	-	-	-	-	-	-	20	-	-	27	-	-
Re-injury		-	-	-	-	-	-	???	-	-	7	-	-
Injury incidence													
Match	30.3	72.8	139.5	49.3	113.4	81 (51^{TL})	73 (29^{TL})	36	68.7	45.9	41.6	61.1	40.1
Contact(%)	-	-	80	-	91	73	86		73	-	73	65	-
Training	-	-	-	-	-	-	-	2.1	-	-	2.8	7.9	4.4
Severity													
Minor	-	-	-	83	85	80^{TL}	81 ^{TL}	60	-	50	55	-	81
Severe	-	-	-	4	4	3^{TL}	7 ^{TL}	27	-	5	23	-	3
Injury location													
Head/neck	-	15	8	6	21	15	14	0	9	4	-	8	5
Upper limb	-	9	4	2	3	5	6	9	8	5	-	7	6
Trunk	-	9	14	15	9	4	8	7	10	11	-	8	6
Lower limb	-	62	75	76	59	77	72	83	74	82	-	76	83
Hip/groin	-	-	2	2	-	6	5	11	5	5	-	4	6
Thigh	-	20	11	17	14	18	17	22	15	17	-	24	26
Knee	-	23	19	23	10	13	16	11	12	18	-	11	10
Lower leg	-	6	17	11	23	17	18	11	21	20	-	16	15
Ankle	-	13	20	17	12	15	12	15	17	17	-	14	14
Foot	-	-	6	6	-	8	4	13	4	5	-	7	9
Injury type													
Joint & lig.	-	12	17	30	13	14	9	22	21	25	-	14	17
Musc & tend.	-	25	10	8	3	23	7	27	13	20	-	25	28
Contusion	-	41	62	38	65	50	71	11	51	45	-	37	30
Fracture	-	4	0	0	1	2	1	9	1	1	-	2	3
Concussion	-	1	1	2	1	2	0	-	1	1	-	1	1

*TL Time-loss; *One training session or match; ^the day after the injury*

Injury pattern

In table 2, injury type and body location have been reclassified according to the consensus statement (Fuller et al., 2006) to facilitate comparison between different studies. The majority of injuries recorded have an acute onset, with overuse injuries accounting for 9% to 39%. However, as mentioned, a significant proportion of overuse injuries do not lead to time loss from sports participation; players often continue training and playing games even when limited by pain and reduced function. Studies based on an injury definition requiring time loss from football therefore lead to a substantial underestimation of overuse injuries (Bahr, 2009).

More than 75% of all injuries affect the lower extremities, mainly the thigh, knee, lower leg and ankle. Early studies of the injury risk among male elite players found that the knee was the most common injury location. Recent studies indicate a possible shift towards an increased proportion of thigh injuries. This is also supported by the observation of a parallel increase in the proportion of muscle and tendon injuries compared to injuries to joints and ligaments.

Studies from the national team level indicate a slightly different injury pattern compared to the club level with more time-loss injuries to the head (6-21%) and lower leg (11-20%). There also seems to be an increased representation of contusion injuries (38-50%). It must be noted that studies from the national team level have used a "physical-complaint" definition, thus making it difficult to compare to studies from the club level using a "time-loss" definition.

Table 2 shows that the difference in injury incidence and injury pattern varies significantly between different studies. The training incidence varies with a factor of ten, and the match injury incidence with a factor of three. A recent study from Champions League found an increased overall and training injury incidence among teams from northern parts of Europe, this was thought to be explained by climatic differences (Waldén et al., 2011a). To date ethnicity and injury incidence and pattern has not been evaluated thoroughly. In addition, differences in injury recording methods and design could lead to differences in injury incidence and pattern. A weakness of the studies in Table 2 is the lack of validation; none of the studies have tested the validity and reliability. Thus, there is a possibility of over-/underestimation of the injury incidence in the different studies.

Injury severity

Severity of injury has in the literature most commonly been presented as the duration of absence from training and match play. As shown in table 2, between 27-69% of all injuries are minor, i.e.

players are able to return to full activity within a week. Severe injuries, leading to absence from training over 4 weeks, are responsible for between 11-35% of all injuries. The greater part of severe injuries are sprains, most commonly to the knee joint, fractures and hamstring strains (Chomiak et al., 2000; Ekstrand et al., 2011c; Waldén et al., 2005a).

Long-term consequences

Acknowledging the high risk of injuries in football, a question is the potential for long-term sequelae resulting from these injuries. Severe injuries such as ACL tears, but also in some cases strains and other sprains may be career-ending. In an English survey, Drawer and Fuller (2001) showed that 2% of professional football players in England retired each year due to injury and nearly 50% of former players responded that they had retired due to injury. Most of the players reported chronic problems as cause of retirement (58%), most commonly of the knee, lower back and hip (Drawer and Fuller, 2001). Of the acute injuries, most were knee injuries, followed by ankle and lower back. On the amateur level, social reasons was the most common explanation for retirement; nevertheless, 22% retire because of injury problems (Ekstrand et al., 1990).

It has been well documented that knee injuries, especially ACL injuries, increase the risk for early development of osteoarthritis (Roos, 1998; Drawer and Fuller, 2001; Turner et al., 2000; von Porat et al., 2004; Øiestad et al., 2009; Myklebust and Bahr, 2005), with the knee reported as the most commonly affected joint. The most important risk factor for early development of osteoarthritis is a history of previous injury to the affected joint. Combined knee joint injuries have a higher prevalence of osteoarthritis development compared to isolated ACL injuries (Øiestad et al., 2009).

In addition, studies have found an increased incidence of osteoarthritis among former football players compared to the normal population, indicating an inherent risk of osteoarthritis development among football players (Klunder et al., 1980; Roos et al., 1994; Lindberg et al., 1993; Larsen et al., 1999). In contrast, a recent study found no difference in the prevalence of low back pain among former endurance athletes with specific back loading compared with non-athletes. This indicates that years of prolonged and repetitive flexion or extension loading in endurance sports do not lead to more low back pain (Foss et al., 2012).

With a time-loss injury definition, the proportion of head/neck injuries ranges from 2% to 9% (Table 2), however, the definition of concussion has varied, as has the registration methods, thus, the incidence of concussion is thought to be underreported in most studies (Straume-Naesheim et al., 2005). The acute effect of concussion on neuropsychological functions is widely discussed.

A meta-analysis has not been able to identify neuropsychological deficits attributable to minor head traumas beyond 7 days post impact for sports-related concussion (Belanger and Vanderploeg, 2005). However, several studies have found an impaired cognitive level after concussion. Straume-Næsheim et al. (2009) found through a case-control study that players suffering minor head traumas had reduced neuropsychological performance. This is supported by studies from American football and Association football (Guskiewicz et al., 2007; Matser et al., 1998; Matser et al., 1999; Matser et al., 2001). A study from Pellmann et al. (2004) found that around 2% of all athletes suffering from concussion have signs of post-concussion syndrome (PCS). The main physical symptom of post-concussion syndrome (PCS) is headache, other symptoms includes reduced concentration and memory, anxiety, nausea and dizziness lasting beyond three months after the impact. Chronic neurocognitive impairment can present in post-concussion syndrome or after a symptom-free interval. In addition, it has been showed that players with a history of concussion have a higher incidence of reduce neurocognitive functioning and increased depression rates (Guskiewicz et al., 2007).

Magnetic resonance imaging studies have found abnormal brain activation in sports-related concussion. In addition, autopsies have shown long-term neurological sequelae of concussion as chronic traumatic encephalopathy. Chronic traumatic encephalopathy, a post-mortem diagnosis, is linked with symptoms of dementia, aggression, depression appearing many years and even decades after the concussion episode. CTE have also been found among athletes without reported concussion episodes, indicating a possible risk with sub-concussive blows. The studies of chronic traumatic encephalopathy and chronic neurocognitive impairment to date are small, and large-scale, epidemiological studies are required to clearly understand the causes and consequences of concussions (Harmon et al., 2013).

Risk factors for injury

An important part of van Mechelen's four-step sequence of injury prevention research is to establish the etiology, i.e. the mechanisms and risk factors for sports injuries (van Mechelen et al., 1992). A variable associated with injury is called a risk factor. Traditionally, risk factors are separated into two categories; internal and external (Meeuwisse, 1994). Internal risk factors are individual biological and psychosocial characteristics predisposing a person to the outcome of a musculoskeletal injury (Meeuwisse, 1994). External risk factors are independent of the injured person and are principally related to the type of activity during the incident of injury (Meeuwisse, 1994). Bahr & Holme (2003) outline three different methods to study risk factors for sports injuries: case-control studies, cohort studies and intervention studies (preferably RCTs) (Bahr and Holme, 2003). The preferable study design is the prospective cohort study, as it can provide direct and accurate estimates of incidence and relative risk (Bahr and Holme, 2003).

In 1994, Meeuwisse proposed a multifactorial model to study the causation of sports injuries. Internal risk factors (e.g. age, gender, injury history, flexibility) are predisposing, but seldom sufficient to cause injury (Meeuwisse, 1994). External risk factors have an impact from without, and include factors such as surface, rules, equipment and weather (Meeuwisse, 1994). Thus external risk factors, as shoe-surface interactions and protective equipment, can modify the internal risk factors, and together determine injury proneness. However, internal and external factors are usually not sufficient to explain an injury; the final piece in the puzzle is the inciting event (Meeuwisse, 1994). Later this model was modified by Bahr & Krosshaug (2005), concluding that there is a need for detailed information about the inciting event to fully understand the causes of injury (figure 1). Hence, information about the playing situation, player and opponent behavior, as well as a description of whole body and joint biomechanics at the time of injury may provide important clues as to how injuries may be prevented. However, to address the potential for prevention, information about injury mechanisms must be considered in a model that takes into account how internal and external risk factors can modify injury risk (Bahr and Krosshaug, 2005).

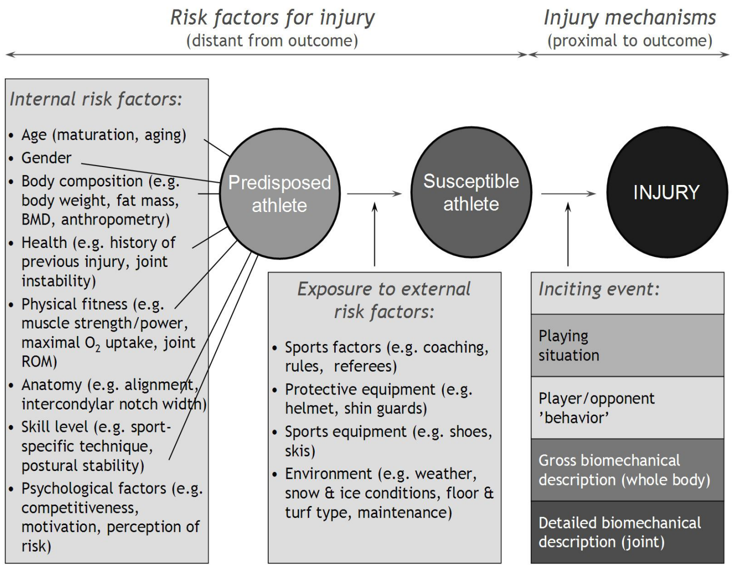

Figure 1. Multifactorial model for injury mechanism (Bahr & Krosshaug, 2005)

Meeuwisse (2007) argued that these current models consist of a linear paradigm, that events follow each other sequentially from a starting point to an end point, and that this does not mirror the true nature of sport injuries. Meeuwisse (2007) therefore introduced the need for a dynamic approach, where a risk factor may be altered as the athlete participates and adapts to the environment or to potentially injurious situations without sustaining an injury.

Whether internal or external, a risk factor is either modifiable or non-modifiable. Modifiable refer to those which can be altered by injury prevention strategies (Emery, 2005). In contrast, non-modifiable risk factors are not affected by injury preventive measures. However, non-modifiable risk factors may influence the relationship between modifiable risk factors and injury (Meeuwisse, 1991). Some potential risk factors for injury in sports are listed in table 3 (Emery, 2005). In the following section some important injury risk factors will be discussed.

Table 3. Potential risk factors for injury in sports (Emery. 2005).

	External risk factors	Internal risk factors
Non-modifiable	Sport played (and level of play)	Previous injury
	Position played	Age
	Weather	Gender
	Time of season/time in match	
Potentially modifiable	Rules	Fitness level
	Playing time	Strength/flexibility/balance/proprioception
	Playing surface	Biomechanics
	Equipment (protective/footwear)	Psychological/social factors

Non-modifiable risk factors

Age

Youth football

A study from Norwegian youth football found a higher injury incidence among 13 to 16 year old players compared to children aged 6 to 12 years (Froholdt et al., 2009). Furthermore, it has been shown that players aged 14 to 16 had a higher injury risk than 16 to 18 years old players (Peterson et al., 2000; Le et al., 2008).

Senior football

A study of injury risk factors in Icelandic football Arnason et al. (2004) found, using a multivariate logistic regression analysis, that older players (≥ 29 years) had a significantly higher risk of injuries compared to younger players. This was recently supported by a study from Champions League, which found that newcomers to professional football had a lower overall rate of injury compared to established players (Kristenson et al., 2013b). However, newcomers had a higher rate of stress-related bone injuries (Kristenson et al., 2013b). Two studies have found that older players have an increased risk of sustaining hamstring strains (Hägglund et al., 2006; Woods et al., 2004; Arnason et al., 2004a). In contrast, no such association was found in a study of football on the American continent (Morgan and Oberlander, 2001).

Anthropometrics

Anthropometrics can be classified both as a modifiable (weight) and a non-modifiable (height) risk factor. Most studies have found no significant association between different anthropometric variables (height, weight, BMI) and risk of injury in male adult football (Arnason et al., 2004a; Hägglund et al., 2006). In contrast, Dvorak et al (2000) found higher injury rates among players with low body fat (<7.7%).

Gender

Few have compared the injury incidence between male and female football players in the same study. Studies using the same injury definitions and study design have observed a higher injury incidence among male football players for both training and matches (Hägglund et al., 2009; Fuller et al., 2007b; Fuller et al., 2007a). However, Hägglund et al. (2009) found a similar incidence of moderate and severe injuries between genders, even though male players had a higher incidence of injuries leading to absence less than one week. It should be kept in mind that the female players had a lower number of weekly sessions, and the female clubs had smaller medical teams; accordingly, the injury incidence among female football players in this study was probably underestimated due to underreporting. The reduced medical support for female players may also lead to delay in diagnosis and treatment of injuries, leading to longer absence from football activity. In epidemiological studies of injury risk in female football, the match injury incidence varies from 14.3 to 23.6 and the injury incidence from 3.1 to 3.7 when using time-loss registration by medical staff (Ostenberg and Roos, 2000; Tegnander et al., 2008). Thus, the injury incidence in female club football seems to be somewhat lower compared to male club football.

The other studies comparing the risk of injury between genders using the same methodology have been conducted at the national team level, and during tournament play. These studies have shown discrepant results. One study showed a lower incidence of injuries in female football (Junge et al., 2004b), while two more recent studies found no significant difference in injury incidence between the two genders (Junge et al., 2006; Waldén et al., 2007). In a review it was documented that female football players have a 2-3 times higher risk of ACL injuries compared to men; female players are also generally younger when sustaining an ACL injury (Waldén et al., 2011b).

Previous studies have shown that a higher proportion of injuries among male players are due to player-to-player contact, in particular during matches (Hägglund et al., 2009; Junge et al., 2004b).

Level of play

The risk of injury tends to be higher during international matches compared to national league matches (table 2). However, there seems to be no significant difference in the risk of injury between different levels of professional football (Champions League compared to domestic league football) (Arnason et al., 2004a; Hägglund et al., 2005b; Ekstrand et al., 2011c). Few studies have compared the risk at different levels of play using the same methods at the same time. In a study from Danish football no significant difference was detected in the risk of injury between high-skilled and low-skilled players (Poulsen et al., 1991). In contrast, a study from Czech football found a significantly higher risk of injury among low-level players both at the senior and youth level (Peterson et al., 2000). In contrast, Soligard et al. (2010) found in a Norwegian study that high skill was a significant risk factor for injury in female youth football.

Previous injury

Many different definitions of re-injury have been used over the years, leading to substantial differences in the reported risk of re-injury. Studies where re-injury has been defined as an injury of the same type and at the same site within 2 months after return to full participation from the index injury, have found that the proportion of re-injuries ranges between 12 and 35% (Ekstrand et al., 1983; Ekstrand et al., 2011c). Other studies, without any time limit, have found a re-injury rate between 22% and 42% (Hawkins and Fuller, 1999; Nielsen and Yde, 1989). In addition, studies have shown that re-injuries cause a longer absence from football activity than index injuries (Ekstrand and Gillquist, 1983; Waldén et al., 2005a; Ekstrand et al., 2011c).

Previous injury has been identified as a risk factor for new injuries to the knee, groin, ankle and thigh (Arnason et al., 2004a; Hägglund et al., 2006; Engebretsen et al., 2010b; Engebretsen et al., 2010c; Engebretsen et al., 2010d; Waldén et al., 2006). Studies in both football and other sports have shown that previous ankle injury is a risk factor for new ankle sprains. Arnason et al. (2004)

found that players with a history of ankle sprains had more than five times higher risk of a new ankle sprain. Engebretsen et al. (2010) found that the number of previous ankle sprains proved to be a significant predictor of new ankle injuries (Engebretsen et al., 2010a); this was supported by an English analysis of ankle sprains (Woods et al., 2003). In contrast, a risk factor study from Swedish football found no relationship between previous ankle sprains and the risk of a new injury (Hägglund et al., 2006).

Whether previous injury is a non-modifiable or modifiable factor can be argued. An injury might lead to muscle weakness or reduced proprioception, factors that could be improved through tailored strength programs or balance programs, thus reducing the effect of previous injury on re-injury, and making previous injury a modifiable risk factor. The high proportion of re-injuries indicates that insufficient rehabilitation and too early return to football activity are possible risk factors for injury. In addition, the risk of re-injury among players at the highest level of club football (Champions League) is the lowest recorded (12%). This was explained by bigger medical teams, providing more personalized rehabilitation after injuries (Ekstrand et al., 2011c).

Time in match and training

Several studies have reported that more injuries occur towards the end of each half (Engström et al., 1990; Hawkins and Fuller, 1999; Junge et al., 2004a). Ekstrand et al. (2011) found an increased incidence of acute injuries, and also in the subcategories strains, sprains and contusions over time in both the first and the second half. It has been shown that most hamstring and ankle injuries are sustained towards the end of matches (Kofotolis et al., 2007; Woods et al., 2004). These results suggest that fatigue could be a risk factor. Other studies contradict these results, and find no significant different risk of injury between the two halves or during the halves (Arnason et al., 2004a; Chomiak et al., 2000).

Time in season

The injury incidence has been reported to vary over different periods of the season, with peaks during the preseason, the mid-season breaks and intensive match periods (Engström et al., 1990; Hawkins and Fuller, 1999; Junge et al., 2004a). An audit of preseason injuries in English professional football found that players were at greater risk of slight and minor injuries, overuse injuries and lower leg (Achilles tendon) injuries during the preseason (Woods et al., 2002). This finding was recently supported by Ekstrand et al. (2011), who documented an increased risk of overuse injuries and lower risk of traumatic injuries during the preseason. That congested match periods have a higher risk of injury is supported by Dupont et al. (2010). They found, in a study of the effect of playing two matches per week vs. one, that the recovery time was sufficient to maintain the level of physical performance, but that injury rate increased significantly when playing two matches per week (Dupont et al., 2010). However, a recent study found no difference in injury risk over a period of 26 days with 8 matches compared to a period with less matches (Carling et al., 2012). One study has shown that most ankle injuries occur during the first two months of the season (Kofotolis et al., 2007). In Norway, the league starts in April and end in November, with the pre-season starting in January. In contrast, most European leagues start in August and end in May, with a 6-week preseason. In Paper II, we wanted to evaluate whether there the risk of injury is different during the preseason compared to the competitive season.

Modifiable risk factors

Foul play

Between 15% and 29% of all acute match injuries at the elite level result from foul play (i.e. a free kick given by the referee, as reported by the medical staff). A British study found that nearly 60% of the remaining injuries were due to physical contact between players; whether the player-to-player contact was a violation of the rules or not was not stated (Hawkins and Fuller, 1999). In a study of psychological characteristics of football players, Junge et al. (2000) found that players have insufficient respect for the Laws of the Game. In addition, nearly all players were ready to commit a "professional foul" if necessary and a majority stated that concealed fouls were a part of the game.

Andersen et al. (2004) showed that less than one-third of injuries identified on video and only 40% of situations with a propensity for injury resulted in a free kick being awarded. In addition they showed that only 10% of all incidents led to a yellow or red card being awarded, and only about 10% of the yellow and red cards awarded during the season were given in situations with a high propensity for injury. The authors therefore concluded that player cautions and expulsions are primarily used for rule violations other than those associated with a high risk of injury (Andersen et al., 2004d). This was verified through a retrospective blinded evaluation of the referee decisions, which showed a good correlation (85%) between the referee panel and decisions of the match referee. The authors therefore concluded that there may be a need for an improvement of the Laws of the Game or their application to protect the players from injury (Andersen et al., 2004b). Thus, in Paper V we have evaluated whether a stricter enforcement of the existing rules can reduce the potential for injuries in male professional football.

Fitness

Muscle strength deficiency has been proposed as one of several risk factors for hamstring injury. A small Swedish study (n=30) showed that low eccentric muscle strength was a significant risk factor for hamstring strains (Askling et al., 2003). Arnason et al. (2004) found no association between concentric quadriceps strength and the risk of quadriceps strains. Croisier et al. (2008) have shown that a low hamstring/quadriceps ratio was a predictor of hamstring injury. It has also been documented that players with untreated side-to-side differences in isokinetic hamstring parameters had an increased risk of hamstring injuries compared to those without differences between the two thighs (Croisier et al., 2008). Two studies found no association between the risk of injury and endurance in male senior football (Dvorak et al., 2000; Arnason et al., 2004a). However, as previously stated, it has been shown that muscle injuries are more frequent towards the end of each half. Thus, fatigue might represent an important risk factor for muscle injuries (Ekstrand et al., 2011c; Ekstrand et al., 2011b; Hawkins and Fuller, 1999).

Psychological factors

Several studies have found that athletes with previous stressful life-events have an increased risk of injury (Junge et al., 2000; Steffen et al., 2009; Rogers et al., 2003; Dvorak et al., 2000). Athletes reporting low levels of social support and coping skills have an increased risk of injury (Smith et al., 1990; Johnson and Ivarsson, 2011). Other studies have found no relationship between coping strategies and injury (Steffen et al., 2009; Ivarsson et al., 2013). A recent study from Ivarsson et al. (2013) found that the traits anxiety, negative life-events, stress and high levels of daily hassle were predictors for injury; however, no relationship between coping strategies and injury were detected. Previously, it has been shown that injured players tend to be more risk-seeking (Junge, 2000). It has been shown in both youth and senior football that previously injured players have a perception of a performance climate (Steffen et al., 2009); however, in the prospective part of the same study a mastery climate was a risk factor for new injury.

Surface

Grass is the traditional playing surface in football both for matches and training at the professional level. However, many regions of the world suffer from climatic conditions that limit natural grass growth throughout all seasons. It is therefore difficult to maintain adequate natural grass pitches both in cold and wet climate zones in the northern hemisphere and in dry areas around the Equator. Artificial turfs have inherent advantages such as longer playing hours, lower maintenance costs, better resilience to tough climatic conditions, and multi-purpose application

(FIFA, 2009). Consequently, some national football associations, including the Norwegian, recommend artificial turf for new football pitches. Artificial turf is becoming a common playing turf not only among youth but also in professional football.

Since its introduction in the 1970s, artificial turf has been developed and refined continuously. The first and second generations of artificial turfs had excessive hardness and shoe-surface traction as two main factors contributing to surface-related injuries (Nigg and Yeadon, 1987). Indeed, data from the 1980s and 1990s indicate that the risk of injury on first and second generations of artificial turf was higher than on natural grass (Engebretsen and Kase, 1987; Arnason et al., 1996). These findings, as well as playing characteristics deviating from natural grass, spurred the development of a third generation of artificial turf, consisting of long grass-like fibers with sand and rubber particles in between. Third generation artificial turf (3GAT) was formally recognized in the Laws of the Game in 2004 (FIFA, 2009). With adjusted hardness and traction, the playing characteristics and movement patterns on the new artificial turfs better resembled those on grass (Andersson et al., 2008). However, concerns have been raised that the injury risk of playing on third-generation artificial turf may still be higher compared with playing on grass.

In 2006, Ekstrand and co-workers published the first study looking at injury risk on artificial turf in male professional football. They found no major differences in injury risk between artificial turf and natural grass except, surprisingly, a higher incidence of ankle sprains on artificial turf (Ekstrand et al., 2006). Studies in college and youth football have revealed a similar risk of injury on natural grass compared to artificial turf (Fuller et al., 2007b; Fuller et al., 2007a; Steffen et al., 2007; Soligard et al., 2012), while Steffen and co-workers (2007) found a higher risk of severe match injuries on artificial turf. However, some of these studies included exposure to football on second generation artificial turf. Therefore, in Paper III, we evaluated the risk of injury solely on third generation artificial turf in Norwegian male professional football, compared to the risk of injury on natural grass.

Injury mechanisms

It has previously been argued that sports injury surveillance systems cannot contribute to the identification of the injury mechanism (van Mechelen, 1997). This was supported by Krosshaug et al. (2005), who emphasized the lack of universally accepted definitions for contact and non-contact injuries. In addition, medical staff reports and player interviews are vulnerable to recall bias, and injuries commonly occur in complex settings, where the speed is high and several players are involved (Krosshaug et al., 2005). Most studies on injury mechanisms in football have been based pm information provided by medical staff. These have reported tackling and collisions as the most frequent injury mechanisms in male adult football, followed by running/sprinting and shooting (Inklaar, 1994b; Dvorak and Junge, 2000; Arnason et al., 1996)

The injury mechanisms in football are naturally separated into contact and non-contact injuries, with player-to-player contact responsible for between 44% and 59% of all acute match injuries at the club level (Ekstrand and Gillquist, 1983; Arnason et al., 1996; Hägglund et al., 2005b; Ekstrand et al., 2011c). The corresponding figure seems to be higher during international tournaments (i.e. World Cup, European Championship and Olympic Games), where it has been reported that between 65% and 91% of all match injuries are the result of player-to-player contact (Junge et al., 2004b; Dvorak et al., 2011). The proportion of injuries due to player-to-player contact is higher during match play than football training; this could possibly be explained by the higher intensity in matches.

Another approach to describing the inciting event for football injuries is video analysis, especially when describing the playing situation and athlete/opponent movement and behavior (Krosshaug et al., 2005). The quality of video recordings has traditionally been a limitation; however, in recent years the image quality, the number of camera views available and the resolution have improved tremendously. Another limitation, which must be kept in mind when interpreting the results, is that only about half of all injuries in football matches are identified on video (Arnason et al., 2004b; Andersen et al., 2004d). It should also be noted that the capture rate of injuries varies with injury type, with all head injuries captured, about half of ankle and knee injuries, while only one third of hamstring strains were captured using video analysis (Andersen et al., 2004d).

In a small study of 10 games in the English Premier League during the 1999-2000 season it was documented that the highest risk of injury was when challenging for ball possession, with a higher risk during the first and last fifteen minutes of the match (Rahnama et al., 2002).

A study of the mechanisms of foot and ankle injuries, where video of the injury was available for 76 (67%) of 114 situations, showed that 95% of the ankle and foot injuries were due to player-to-player contact (Giza et al., 2003). However, as a substantial number of injuries were not available for video analysis, the proportion of non-contact ankle and foot injuries was probably underestimated. The majority of the injuries occurred to the weight-bearing limb, and due to tackles involving lateral and medial forces that created corresponding eversion and inversion rotation of the foot (Giza et al., 2003; Fuller et al., 2004c; Andersen et al., 2004c). It is also stated that significantly more injuries occurred from tackles where the tackling player stayed on his feet during the tackle.

The most common cause of head injuries and high-risk head situations are head-to-upper extremity contact, followed by head-to-head contact (Fuller et al., 2004c; Andersen et al., 2004d). In contrast, a study from English football found that elbow use was the injury mechanism in only 1% of the match injuries (Hawkins et al., 2001). Andersen et al. (2004d) found that most incidents with a high risk of head injury occurred during heading duels. Despite of the arm often being used actively in the heading duel, a foul was called in less than one third of the incidents. Fuller et al. (2004) found through video analysis that referees identified only 40% of head/neck injuries as foul play during FIFA tournaments. It has therefore been suggested that awareness about the injury potential of arm-to-head incidents is lacking among referees (Fuller et al., 2004a).

Arnason et al. (2004b) observed that the exposed players in incidents with high risk of injury appeared to have their focus away from the opponent that challenged him for ball possession in 93% of the cases. In another study of high-risk injury situations and injuries in Norwegian football, the exposed player appeared to have his attention directly towards his primary duelist in only 2% of all incidents and in none of the injuries recorded on video (Andersen et al., 2004d). Video analysis of European international matches and English professional matches has shown that significantly more free kicks were awarded during international matches (Hawkins and Fuller, 1998). In the same study, it was shown that despite only 15-28% of all injuries resulting from foul play, most injuries were due to player-to-player contact. The mechanisms of player-to-player contact in the non-foul situations were found to be tackling duels, heading duels and unintentional collisions (Hawkins and Fuller, 1998).

However, no studies have evaluated the characteristics and changes of player-to-player contact and situation with a propensity for injury over time. We therefore wanted to compare the rate of incidents, situations with a propensity for injury, from the 2000 season to the 2010 season. In addition, we wanted to compare the rate and characteristics of duels between the two seasons. These issues were addressed in Paper IV.

Injury prevention in football

With the high injury incidence and serious consequences of injury in football, injury prevention is essential. The vast majority of research in the field of football medicine has been descriptive epidemiological studies and risk factor studies. A literature search on PubMed using the following search term "prevent*" and (injury OR injuries) and (football OR soccer), revealed 219 studies. The reference lists of retrieved articles were checked manually for potentially relevant studies. A total of 14 studies were found when the search was narrowed to injury preventive studies in senior male football. The studies ranged from the use of orthoses, eccentric strength training, balance training, video-based awareness to multi-modal exercise programs. Of these 14 studies, 10 have demonstrated a reduction of injury incidence in the intervention group. Table 4 summarizes the injury prevention studies in male football.

In 1981, Ekstrand and co-workers conducted the first published randomized controlled trial on injury prevention in football (Ekstrand et al., 1983). The intervention group was introduced to a seven-component program. The risk of injury was reduced by 75% in the intervention group compared to the control group. In addition, there was a significant reduction in the risk of muscle strains, as well as of ankle and knee sprains. The major limitation of this study is the implementation of seven different preventive measures, making it difficult to assess the individual contribution of the each of these features.

After this, Tropp and co-workers (1985) assessed the effect of balance training and use of orthoses on ankle sprains. A total number of 439 players were allocated to three groups; a control group, an orthosis group and a balance training group (ankle disk). The authors found that both ankle disk training and the use of orthoses reduced the incidence of ankle sprains among players with previous ankle sprains. In a similar study, Surve et al. (1994) evaluated the effect of a semi-rigid ankle orthosis on ankle sprains. The players were divided into two groups: players with previous ankle injury and players without previous ankle injury. The two groups were then randomly allocated to an intervention group (using semi-rigid orthosis) or control group. The main finding was that players with a previous history of ankle sprains reduced their risk of a new ankle injury by 60% using orthoses. They found no significant effect on the risk of ankle sprains in previously uninjured ankles. In a study from Iran, no reduction in ankle sprains was seen among players with a history of ankle sprain when using Sport-Stirrup orthosis or a strength training program for the evertor muscles (Mohammadi, 2007). However, a proprioceptive training program using an ankle disk 30 minutes a day resulted in a significantly lower risk of new ankle injuries.

Caraffa et al. (1996) evaluated the effect of gradually increasing proprioceptive training on four different types of wobble-boards on the risk of ACL injuries. The risk of ACL injuries was significantly reduced in the proprioceptive training group.

The rate of hamstring injuries in football is high (table 2); thus, hamstring injuries have been the focus of several prevention studies. In a study from Askling et al. (2003), the intervention group was assigned to specific hamstring training with eccentric overload using a YoYo flywheel ergometer during the preseason. They found that 70% fewer players in the intervention group sustained a hamstring injury during the following season. The training group also showed a significant increase in muscle strength and speed. Later, Mjølsnes et al. (2004) found that a 10-week training program with Nordic Hamstrings (eccentric training) was more effective in increasing eccentric hamstring strength, the hamstrings/quadriceps strength ratio and isometric hamstring strength, than traditional hamstring curl training (concentric training). The authors therefore suggested that performing Nordic Hamstring regularly might prevent injuries. This was later confirmed by Arnason et al. (2008) who found that the incidence of hamstring injuries was lower in teams who used Nordic hamstring combined with warm-up stretching. No difference was found when performing flexibility training alone (Arnason et al., 2008). This was recently supported by a RCT in Danish football that reported a lower rate of overall, new and recurrent acute hamstring injuries after a 10-week progressive eccentric training program during the midseason break followed by a weekly program during the competitive season (Petersen et al., 2011).

Hölmich and co-workers (2010) implemented a similar approach to reduce the risk of groin injuries among male football players. The RCT included 1211 players, where the intervention program included six exercises; strength training (concentric and eccentric), core stability, stretching and coordination. However, no significant effect of the intervention program was detected.

A Norwegian study by Engebretsen et al. (2008) aimed to identify amateur players with an increased risk of injury based on injury history and reduced function through a questionnaire. The players identified as having a high risk of injury were randomized to an intervention group or a control group. The players in the intervention group were provided with an exercise program based on their injury history and asked to complete it three times a week for 10 weeks during preseason. The screening was able to identify the players with an increased risk of injury through the questionnaire; however, they found no effect of the intervention program on the risk of injury (Engebretsen et al., 2008). It should be noted though, that compliance was low, with less than 30% of the players at risk completing their prescribed training programs.

Table 4. Summary of the study population, methods and results of injury prevention studies in male football

Reference	Level of play	N	Injury definition	Study design	Preventive measure	Outcome measure	Main finding
Ekstrand et al. (1983)	Amateur	180	Time-loss (>1 week)	RCT	7-modul program	Overall injury incidence	75% reduction of injuries in the intervention group
Tropp et al. (1985)	Amateur	439	Time-loss (≥1 day)	RCT	Orthosis & balance training	Ankle injury incidence	Reduced risk of ankle sprains in both the orthosis and training group.
Surve et al. (1994)	Amateur	504	Time-loss (≥1 day, missing next match)	RCT	Orthosis	Ankle injury incidence	60 % lower risk of ankle re-injury in the orthosis group
Caraffa et al. (1996)	Amateur	600	ACL injuries (arthroscopy)	Prospective cohort study	Balance training	ACL injury incidence	87% lower risk of ACL injuries in training group
Askling et al. (2003)	Elite	30	Time-loss (≥1 day)	RCT	Eccentric training in special device	Hamstring injury incidence	70% fewer players in intervention group sustained a hamstring injury
Arnason et al. (2005)	Elite	271	Time-loss (≥1 day)	RCT	Video-based awareness program	Overall injury incidence	No difference in injury risk
Hägglund et al. (2007)	Amateur	582	Time-loss (≥1 day)	RCT	Coach-controlled rehabilitation program	Re-injury incidence	Reduction in injury risk in the intervention group.
Mohammadi et al. (2007)	Elite	80	Physical complaint	RCT	1. Proprioceptive training 2. Strength training 3. Orthosis	Incidence of recurrent ankle sprains	78% reduction of recurrent ankle sprains after proprioceptive training
Fredberg et al. (2008)	Elite	209	Physical complaint	RCT	Eccentric training and stretching of patellar and Achilles tendon	Achilles and patellar tendinopathy	No difference in injury risk between the intervention and control group
Arnason et al. (2008)	Elite	NA	Time-loss (≥1 day)	Prospective cohort study	Eccentric training (Nordic hamstring lowers) Flexibility training	Hamstring injury	Reduced risk of hamstring injuries in the Nordic Hamstring group. No difference in the flexibility group
Croisier et al. (2008)	Professional	462	Severe injuries/MRI/US/PE	Prospective cohort study	Strength training	Hamstring injury incidence	Reduced risk of hamstring injuries in the group that normalized isokinetic parameters
Engebretsen et al. (2008)	Amateur	525	Time-loss (≥1 day) Non time-loss for groin and hamstring	RCT	Neuromuscular training Nordic hamstring Groin strength training	Lower extremity injury incidence	No difference in injury risk
Hölmlich et al. (2009)	Amateur	977	Medical attention	RCT	Six exercises (strength, stretch)	Groin injury incidence	No difference in injury risk
Petersen et al. (2011)	Amateur & professional	942	Physical complaint	RCT	Eccentric training	Hamstring injury incidence	Reduced rate of overall, new and recurrent acute hamstring injuries

Fredberg et al. (2002) have shown that asymptomatic soccer players with an increased risk of developing patellar and Achilles tendon injuries within the next 12 months can be identified by ultrasonography. The study group initiated an RCT in order to prevent the occurrence of tendon injury among players with asymptomatic tendon changes. Twelve teams were randomized to take part in the intervention or the control group. The intervention program consisted of eccentric training and stretching of both the patellar and Achilles tendon three times weekly. In contrast to the hypothesis, players with asymptomatic ultrasonographically abnormal patellar tendons who were assigned to the extra training in the intervention group had an increased risk of injury. Players in the intervention group with normal ultrasonography had a significantly lower risk of developing ultrasonographically abnormalities, but the intervention program had no effect on the risk of injury.

After studying situations with a propensity for injury in Icelandic football, Arnason et al. (2005) wanted to test the effect of a video-based awareness program on the incidence of acute injuries. Teams from the top two divisions in Icelandic football were randomized to an intervention group and a control group. The intervention teams were visited prior to the league start and given information on the risk of injury, typical injuries and their mechanism. However, no significant differences in the risk of injury between the intervention and control group were detected.

Most injury prevention studies have been aimed at the players and different training regimens; thus, Hägglund et al. (2007) changed the focus to the coaches. Their intervention was implemented by team coaches, and consisted of information about risk factors for re-injury, rehabilitation principles and a 10-step progressive rehabilitation program including return-to-play criteria. The controlled rehabilitation program resulted in a 66% reduction of re-injuries in the intervention group for all injuries and 75% reduction for lower limb injuries. In addition, the compliance with the rehabilitation program was high; 68% of the players followed the recommended number of training sessions before return to play.

The proportion of acute match injuries due to player-to-player contact is high; therefore, reduction of foul play has been proposed as a possible intervention to reduce injury rates in football (Dvorak et al., 2000). A German study showed that coaches can positively influence both the understanding of fairness and fairness behavior of young footballers. Thus, they emphasized that coaches should be challenged to serve as role models, by exemplifying fair play by their own actions (Pilz, 2005). In addition, White et al. (2013) showed that coaches are receptive to implementation of injury preventive measures, and suggested that prominent coaches can serve as role models for community-level coaches.

An editorial highlighted that the effects of rules and regulations on injury risk is a key element missing from sports injury prevention research (Matheson et al., 2010). In American football "spearing" was banned in 1976, leading to a significant reduction of catastrophic cervical spine injuries (Heck et al., 2004). In a youth ice hockey tournament, the risk of injury was 4.8 times higher when regular rules were applied compared to "fair play" rules (points for playing without excessive penalties) (Roberts et al., 1996). Video analyses have shown that referees identify only 40% of head/neck injuries as foul play during FIFA tournaments (Fuller et al., 2004a). It has therefore been suggested that knowledge regarding the injury potential of arm-to-head incidents is lacking among referees. As a consequence, the International Football Association Board gave referees the authority to sanction potentially injurious fouls, such as intentional elbows to the head, with automatic red card (Dvorak et al., 2007). After this, the incidence of match injuries was significantly lower in the 2010 FIFA World Cup for men compared to the mean incidence found in the three previous World Cups (Dvorak et al., 2011). This was partly explained by stricter rule enforcement. However, the effect of rule changes and a stricter interpretation and enforcement of the Laws of the Game have neither been evaluated through prospective injury surveillance systems nor using systematic video analyses. No previous prospective studies have evaluated the effects of rule changes on the risk of injury in football

We therefore wanted to assess whether stricter interpretation of the Laws of the Game could reduce the potential for injuries in Norwegian male professional football. This is addressed in Paper V.

Aims of the thesis

The general aim of this thesis was to reduce the risk of injuries in Norwegian professional football. A continuous injury registration system was established in 2000 to reveal the extent of the injury problem and the causes of injury, in order to develop and introduce injury preventive measures.

The specific aims of this thesis were:

I. To assess the accuracy of a prospective injury registration system based on medical staff reporting by comparing it to retrospective player interviews (Paper I).

II. To monitor changes in the incidence of injury and injury pattern in Norwegian male professional football over seven seasons (Paper II)

III. To evaluate if there was an increased risk of injury during the preseason compared to the competitive season (Paper II).

IV. To compare the risk of acute injuries on natural grass to third-generation artificial turf in male professional football (Paper III).

V. To compare the incidence of situations with a propensity for injury during the 2000 season to the 2010 season in Norwegian male professional football, with a particular focus on tackling characteristics (Paper IV).

VI. To assess whether more strict interpretation of the Laws of the Game could reduce the potential for injuries in Norwegian male professional football (Paper V).

Methods

Study population (Paper I-V)

This thesis is based on a prospective injury surveillance system in the male Norwegian professional football league (Tippeligaen), established by the Oslo Sports Trauma Research Center in 2000 (Andersen et al., 2004d). Its main objective is to survey injury incidence and injury trends over time. We invited all players with a first-team contract to participate in the study, but did not include players on trial or youth players without a professional contract. Paper I includes information from July through October 2007, paper II includes data from 2002 through 2007, paper III includes data from 2004 through 2007, and paper V includes the 2010 and 2011 seasons.

Validation of injury registration (Paper I)

Study design

Paper I is a methodological study comparing two different injury recording methods during three months of the 2007 season. The first method was the prospective injury registration, where the medical staff of each club was asked to record all injuries sustained throughout the season (January – November) by players with a first team contract. The second registration method was retrospective interviews with the players in October about all injuries sustained during three of the four final months that season (i.e. from July through September). The team medical staff was kept unaware of the player interview sessions we planned to do toward the end of the season.

Player interviews

Physicians and medical students from OSTRC completed one-on-one interviews based on a structured interview form that was first developed for volleyball (Bahr and Reeser, 2003) and later also used in World Cup skiing (Flørenes et al., 2011). To facilitate player recall, the interviews were based on a week-by-week schedule of each club's training and match program for the three-month study period. The interviewers were blinded to the data from the prospective injury registration. Player interviews were conducted in quiet and private surroundings. Telephone interviews were carried out with players not present during the team interview sessions. The players were asked if they participated fully in first team training and were available for match selection each week. They were also asked whether or not they were selected for the match squad that week. If they did not participate fully in training or were not selected in the match squad, we asked if they had an injury during that period. If a player reported an injury, we informed him about how we defined an injury and asked when he was able to participate fully in football training. We completed the same injury registration form as used by the medical staff registration. In addition, match previews by the largest newspapers, the homepage of each club and local newspapers were monitored to double check information gained through both player interviews and medical staff registration. We also checked that players claiming to be injured did not appear on the match roster during the period in question.

Injury registration and definitions (Paper I, II, III, V)

A member of the club medical staff, in most cases the physiotherapist, performed the prospective injury registration. The club license in Norway requires that a physiotherapist attends each football activity, training and match throughout the season. We used a time-loss definition, in accordance with the consensus statement, when recording injuries; an injury was registered if the player was unable to take a full part in football activity or match play at least one day beyond the day of injury (Fuller et al., 2006). The player was considered injured until declared fit for full participation in training and available for match selection by the medical staff (Fuller et al., 2006).

According to the onset of an injury, injuries were defined as acute or overuse, evaluated by the medical staff. If the injury was the result of a specific, identifiable event, it was defined as acute. If the onset was gradual, without a single, identifiable event, it was reported as an overuse injury (Fuller et al., 2006). Overuse injuries were not included in Paper III, as they could not be attributed to a specific training session or match (and hence, turf type).

The injury form included information about the date of injury, the type of activity (match or training) in which the injury occurred, injury location and injury history.

The injury surveillance system was implemented prior to the consensus statement, thus the severity categories used in Paper II and III differ from the consensus statement. In Paper II and III we based the classification of injuries on the NAIRS; injuries were categorized according to the duration of absence from match and training sessions as: mild (1-7 days), moderate (8-21 days) and severe (>21 days) (van Mechelen et al., 1992). Papers I and V were completed after the consensus statement; therefore, injuries were categorized into four severities, according to the consensus statement: minimal (1-3 days); mild (4-7 days), moderate (8-28 days) and severe (>28 days) (Fuller et al., 2006).

Prior to the 2010 season, the methodology of the UEFA injury study was implemented, leading to some minor modifications in the injury registration method. Injury severity was categorized according to the consensus statement and the injury card included information on injury mechanism and the referee's sanction.

Forms were collected on a monthly basis and, if needed, we followed up with reminder text messages and phone calls. We checked the injury cards thoroughly when we received them. If information was missing or any other inconsistencies were seen, a member of the study group contacted the medical staff to resolve these.

Exposure registration (Paper II, III and V)

We collected exposure data on a separate form asking for information about the type and duration of match or training, the number of participants and the surface during the particular training or match (Paper II and III). Match exposure for players included all matches between teams from different clubs of players with an A-squad contract. Training exposure was defined as any physical activity carried out under the guidance of a member of the first teams coaching staff. A member of the coaching staff or the medical staff completed the exposure form.

After the implementation of the methodology from the UEFA injury study, exposure registration was altered from the team level to the individual level (Paper V). Individual player exposure to activity in training and matches was registered by the clubs on a standard exposure form in Microsoft Excel. We also included national team exposure.

Video analysis (Paper IV and V)

We collected videotapes prospectively throughout the 2000, 2010 and 2011 seasons to be reviewed by the study group. An *incident* was said to have occurred if the match was interrupted by the referee, the player stayed down for more than 15 s, and appeared to be in pain or received medical treatment. We did not include incidents caused by muscle cramps. Each incident was classified according to predetermined criteria: the cause (opponent-player contact, teammate-player contact, ball-player contact or non-contact) and body location involved. A duel was defined as a situation where two opponents challenged each other for ball possession; duels were classified as heading duel, tackling duel or other duel (screening or running). We also categorized the referee's decision (no foul, foul for, foul against) and the referee's sanction (no sanction, yellow card or red card). In addition, incidents affecting the head were classified by cause (head-to-head, arm-to-head, trunk-to-head, leg-to-head, in addition head-to-ground/ball/object were listed as head-to-other).

We also analyzed all tackling incidents using variables utilized for video analyses of injuries from three FIFA tournaments (Fuller et al., 2004c). The following variables were included: the direction of the tackle (tackling player approached from the front, the side or from behind the tackled player), action during tackle (one-footed tackle, two-footed tackle, use of arm/hand, upper body contact, clash of heads) and tackling mode (tackling player staying on feet, sliding in or jumping vertically). In addition, the study group assessed whether the tackle was late (the tackle occurred after the ball had been passed by the tackled player) and whether the tackling player made contact with the ball (prior or after initial contact with the tackled player) or not (Andersen et al., 2004c). We also classified the tackling incidents in two categories. If the tackled player also tackled, it was indexed as an active tackling duel. However, if the tackled player was tackled by an opponent it was indexed as a passive tackling duel.

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

In addition, we conducted a video analysis of all player-to-player contact situations occurring during match play. We randomly selected 14 matches from the 2000 season and 16 from the 2010 and 2011 season (one home match and one away match for every team). We registered the type of duel (tackling, heading and other). For heading duels we included the contact between the two opponent players (trunk-trunk, head-head, arm-head, foot-head).

Stricter rule enforcement (Paper V)

During the fall of 2010 the Football Association of Norway (NFF) and the Norwegian Professional League Association (NTF) met with the project group from the Oslo Sports Trauma Research Center (OSTRC) and members of FIFA-Medical Assessment and Research Centre (F-MARC) to discuss the implementation of stricter rule enforcement in 2011 in the Norwegian male professional league (Tippeligaen).

Video recordings of situations with a propensity for injury and injuries from the 2010 season were analyzed and refereeing guidelines were agreed upon according to FIFA regulations. This involved sanctioning of two-foot tackles as well as tackles with excessive force and intentional high elbow with an automatic red card. A total of 15 referees and 25 assistant referees were familiarized with the stricter rule enforcement in meetings at the end of 2010 and in a training camp in January 2011.

The plans for stricter rule enforcement were introduced to each of the teams in meetings with referees appointed for the 2011 season. During these one-hour meetings the stricter interpretation of the rules was introduced through video clips, lectures and discussions. After informing the players, the study group and the Head of Refereeing in the Football Association of Norway held a similar meeting for the media. We also organized a press conference which included a high-profile player, manager and FIFA representative a week prior to the start of the season to inform the public.

Outcome measures

The primary outcome measure was the overall rate of contact incidents before and after the introduction of stricter rule enforcement in the 2011 season. Secondary outcome measures were the rate of head contact incidents, ankle contact incidents and contact injuries. Our hypothesis was that stricter rule enforcement by the referees would lead to a reduction in the number of incidents, especially head and ankle incidents.

Statistical methods

Most of the analyses were executed using the Statistical Package for Social Sciences (SPSS) (SPSS for Windows 15.0, SPSS Inc, Chicago, III.).

In Paper I, Kappa (κ) correlation coefficients were calculated for agreement between methods (Altman, 1991). Coefficients of 0.81 to 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 (Altman, 1991).

In Paper II, III and V results are presented as injury incidence (injuries/1 000 hours of exposure) in training and match play. The same method was applied for the analysis of incidents with a high risk of injury with the number of incidents as the numerator. We used a z test and the 95% confidence interval (CI) based on the Poisson model to compare the rate ratio between preseason and the competitive season (Paper II) and natural grass and artificial turf (Paper III), the 2000 season and the 2010 season (Paper IV) the 2010 season and the 2011 season (Paper V).

Correspondingly, the rate ratios (RR) are presented with competitive season, natural grass, the 2000 season and the 2010 season as the reference group. A two-tailed p-value≤0.05 was regarded as significant.

In Paper II, we estimated changes in injury incidence over the study period using linear regression, were the injury incidence was the dependent variable and year as the independent variable. In addition, we used a general estimating equation (GEE) model approach with teams as clustering factor and correlation structure chosen as exchangeable to evaluate changes in injury incidence. A robust estimation method was undertaken. Linear regression and GEE were done in STATA 12. In Paper II, IV and V categorical variables were compared with the χ^2 test.

In Paper III, with natural grass as the reference group we adjusted for the correlation between the dichotomy match/training and both injury and artificial turf/natural grass. Overall injury incidence on natural grass/artificial turf was calculated using a stratified analysis by match/training. The pooled estimate natural grass/artificial turf across the strata (match/training) was made by a weighted average using the reciprocal of the variances of the rates as weights.

Sample Size (Paper V)

We calculated our sample size using a formula for cohort studies with Poisson outcomes (Gail and Benichou, 2000) based on incident rates in the 2000 season, i.e. 75 incidents per 1000 player-match hours (Andersen et al., 2004d). An estimated total of 630 incidents per season would provide an acceptable power of 0.9 at the 5% significant level to detect a 30% reduction in the number of incidents. Correspondingly, an estimate of 180 ankle and head incidents per season would enable us to detect an effect size of 50% for these two categories. Based on an expected incidence of 18 acute injuries per 1000 player-match hours, with 13 participating clubs and assuming that approximately 50% of all injuries would be contact injuries, we expected a total of 50 recorded match contact injuries each season. Thus, we would need a decrease in contact injury incidence of 70% after the introduction of stricter rule enforcement in Norwegian professional football to have a power of 0.9 and a 5% significance level.

Ethics

The studies were approved by the Regional Committee for Medical Research Ethics, Region Øst-Norge and the Norwegian Social Science Data Services. The players received written and oral information about the study, it was emphasized that participation was voluntary. All data collected was treated confidentially.

Results and discussion

Validation of injury registration in Norwegian professional football (Paper I)

During the 2007 season, all 14 clubs in Tippeligaen agreed to participate in the methodological study with both medical registration and player interviews. However, one club was excluded from this study because the medical staff had not provided any information prior to the player interviews. Of 310 eligible players, 296 (95%) were interviewed and included in the study. During the three-month study period, 133 (45%) of the players sustained at least one injury and a total of 174 unique injuries were registered.

We found that medical staff reports underestimated the incidence of time-loss injuries by 19% for the 3-month study period as a whole (Table 5). The study also showed that 30% of the injuries registered by the medical staff were not reported by the players, indicating that there is a significant recall bias associated with retrospective player interviews.

Table 5. Comparison of injuries recorded through medical staff reports, player interviews or both methods.

	Medical staff	Both methods	Player interview
All injuries	52	89	33
July	16	18	4
August	21	28	11
September	15	43	18
Acute injuries	34	66	23
Overuse injuries	18	23	10

For the 89 injuries recorded through both methods, the κ-correlation coefficients for agreement between the medical staff report vs. the player interviews were 0.61 (95% CI 0.48 to 0.74) for injury severity, 0.97 (0.92 to 1.01) for injury type, 0.99 (0.96 to 1.01) for body part injured and 0.89 (0.79 to 0.98) for activity when injured. Of the 33 injuries not recorded by the medical staff, 76 % were minimal or mild (absence < 1 week). Surprisingly, one severe injury was not registered by the medical staff. Of the 52 injuries only reported by team medical staff, 74% lead to absence less than one week. All severe injuries were detected through player interviews.

Injury surveillance

That more injuries are recorded by prospective injury registration compared to retrospective interviews is in accordance with previous studies from football, among preschool children and physical education students (Junge and Dvorak, 2000; Twellaar et al., 1996; Fonseca et al., 2002). In a study by Junge & Dvorak (2000), Czech football clubs were followed on a weekly basis by a physiotherapist to record injuries, after 12-months the players filled out a questionnaire to recall all injuries sustained during the 12-month study period. They found that there is a significant recall bias associated with retrospective player interviews, especially mild injuries sustained one year in the past (Junge and Dvorak, 2000). We tried to minimize the effect of recall bias by limiting the study period to three months, as well as by using a week-by-week schedule of each club's training and match program and asking the players whether they were selected for the match squad or not, and whether they played the match. Nevertheless, player recall appeared to deteriorate month by month. Of injuries occurring during July, 42% were only recorded by the medical staff. For August and September the proportions were 35% and 20%, respectively.

Interestingly, medical staff recording is not necessarily the best injury registration method in all settings. A recent study among elite skiers and snowboarders found that only 61% of all recorded injuries were reported by the medical staff, and that only 6% of the injuries identified were missed by retrospective player interviews (Flørenes et al., 2011). However, in winter sports the teams and athletes travel continuously during the competitive season, thus, injury registration on a regular basis might be difficult for team medical staff. In contrast, football teams spend most of the week in their own training facilities, with team medical staff in attendance most of the time.

Nilstad et al. (2012) compared individual self-reported registration through text messaging to routine medical staff registration in female elite football in Norway. All players received three text messages each week with questions regarding football activity and whether they had sustained an injury. When an injury was reported, the player was contacted by the study group to complete an injury form. Surprisingly, the medical staff missed approximately 2/3 of all injuries, and 50% of all severe injuries (Nilstad et al., 2012). However, the medical staff was not blinded to the athlete registration, and this may have contributed to the low capture rate by the medical staff. In addition, the resources in female football are considerable lower than male football, and team medical staff do not attend training on a day-to-day basis.

Thus, injury registration systems should be tailored, not only to the sport but also the population they are intended for, using different methods in different sports and level of play, depending on the availability of medical staff.

Injury registration in the future

Professional football players are employees, and therefore covered by the same health and safety legislation as other workers (Fuller, 1995). Injury surveillance is a key risk management tool, to monitor injury incidence and injury patterns to ensure the safest possible work environment for the players. Today, injury registration is not compulsory for the clubs and their medical staff. Implementation of injury registration as a requirement to be issued a club license by the national football association would ensure that this important risk management tool is in place.

The accuracy of an injury surveillance system is the responsibility of the study group; it is therefore important to establish routines for ongoing education of the medical staff involved, regular feedback with injury statistics and close follow-up. In the European Championships and FIFA tournaments the medical staff is contacted every third day and after each match, respectively (Walden et al., 2007; Junge et al., 2004a). In addition, the registration of exposure on the individual level allows both the study group and medical staff to verify absences and injury reports. Another possibility is media monitoring; Faude et al. (2006) concluded that media-based injury statistics were almost complete; but the specific diagnosis were not available in all cases. With the technological development over the last decades, web-based injury surveillance system could be the solution to secure the quality of injury registration. This will enable the injury surveillance component to be linked to the player's medical record, and even team schedule and roster. Computer-based systems could be programmed to flag discrepancies automatically. However, it must be underlined that such an surveillance system must take into account the need for strict player confidentiality (Hägglund et al., 2005a). A significant proportion of overuse injuries do not lead to time loss from sports participation; players often continue training and playing matches even when limited by pain and reduced function. Thus, overuse injuries are therefore underestimated in most injury surveillance studies (Bahr, 2009). Based on these observations, Clarsen et al. (2012) developed and validated a new overuse injury questionnaire, where the athletes on a weekly basis registered problems that were suffered. They found that of 419 recorded overuse problems resulting in reduced performance or participation, however, only 142 (34%) resulted in absence from activity. However, no such studies have been conducted in football; thus, the prevalence of playing with pain, reduced function and performance limitations has not been evaluated in football.

The risk of injury in male professional football has been studied extensively, but information regarding the incidence and effects of illness is limited. Recently a couple of reports following one team for several seasons have been published (Orhant et al., 2010; Parry and Drust, 2006).

They have found that the most common causes of absence due to illness are upper respiratory tract problems and gastrointestinal complaints. However, authors concluded that the impact of illness on absence from training and match is minimal, but that the effect on performance is unknown. As noted, these studies have only included one team; thus, there is a need for larger prospective cohort studies including information on illness and problems related to overuse injuries among professional football players.

Change in risk of injury in Norwegian professional football (Paper II)

The aim of Paper II was to monitor injury incidence and pattern over six seasons in Norwegian male professional football. A total of 494 157 player hours of activity were registered during the six-year long study period; 348 521 player hours (70.5%) of football training, 84 503 hours (17.1%) of other training and 61 133 (12.4%) player-match hours. A total of 2 365 injuries were recorded; 1 664 (70.4%) acute injuries and 701 (29.6%) overuse injuries (Table 6).

Table 6. Exposure and injuries over the six-season study period.

Season	2002	2003	2004	2005	2006	2007
No. of teams	12	11	13*	14*	11	12
Exposure (hours)	90 916	80 169	75 421	77 722	80 628	86 284
Football training	67 273	57 555	51 170	55 229	56 134	61 159
Other training	12 058	12 888	13 682	12 097	16 123	17 656
Match	11 586	9726	10 569	10 396	8371	10 486
Injuries (number)	424	422	368	373	332	446
Acute	271	299	248	282	254	310
Football training	115	139	86	106	90	119
Other training	6	10	6	10	6	2
Match	150	150	156	166	158	189
Overuse	153	123	120	91	78	136
Injury incidence						
Acute						
Football training	1.7	2.4	1.7	1.9	1.6	1.9
Other training	0.5	0.8	0.4	0.8	0.4	0.1
Match	12.9	15.4	14.8	16.0	18.9	18.0
Overuse	1.7	1.5	1.6	1.2	1.0	1.5
Acute match injury incidence						
Hip/groin	0.6	1.4	0.6	0.8	1.1	1.3
Thigh	3.2	3.4	2.9	3.2	5.0	4.3
Knee	1.4	2.7	2.9	2.3	3.2	2.6
Lower leg	1.1	1.9	2.3	1.4	1.8	1.9
Ankle	2.9	2.8	1.9	3.1	3.3	3.4

*Three clubs participated with match exposure and acute injuries

Injury incidence

Using the aggregated injury incidence each season as dependent variable in a linear regression model (n=6), the acute match injury incidence showed an increase of 1.06 injuries/1 000 player hours (95% CI: 0.40 to 1.73, p=0.012) (Figure 2) per year. This corresponds to an estimated total increase of 49% over the 6-year observation period. When accounting for interteam variation and clustering effects using a GEE model, the increase in injury incidence was 0.92 injuries/1 000 player hours (95% CI: -0.11 to 1.95, p=0.083). Correspondingly, the aggregated league match injury incidence showed an annual increase of 0.66 injuries/1 000 player hours (95% CI: 0.01 to 1.31, p=0.048), which was not significant when correcting for interteam variation in the GEE model (0.69 injuries/1 000 hours, 95% CI: -0.68 to 2.06, p=0.32). We did not detect any change in the incidence of overuse injuries (p=0.73), nor in acute training injuries (p=0.49) during the six-year study period.

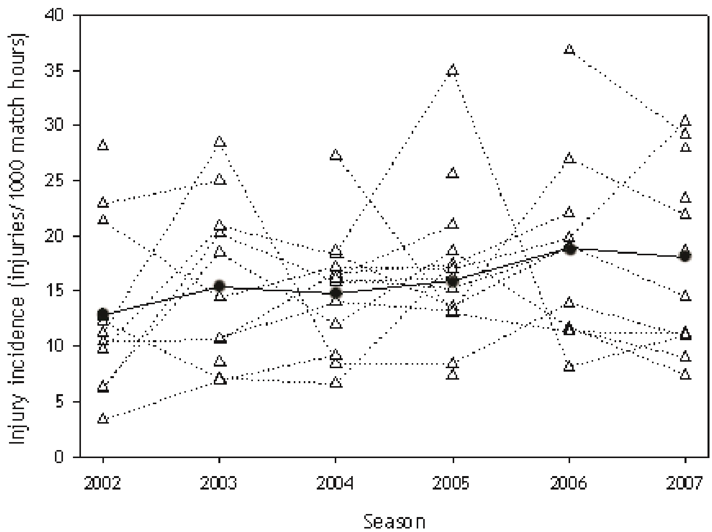

Figure 2. The incidence of acute match injuries for all participating teams over the six-season study period (n=73). The filled circles and solid line depicts the aggregated incidence of acute match injuries.

Has the match injury incidence increased?

The main finding of Paper II was that the overall incidence of acute match injuries increased during the study period; however, using a conservative statistical model correcting for clustering effects showed that interteam variation was substantial. Our results are in contrast to a recent 7-year study from the top European professional level, where no change was seen (Ekstrand et al., 2011c). Notably, we did not find any significant differences in the incidence of acute training injuries or overuse injuries. Due to small numbers we were not able to detect any changes in injury type, location, severity or the proportion of re-injuries during the study period.

While we observed an alarming 49% increase in acute match injury risk during the study period, the results also show that this increase was not fully consistent across teams. This is of course partly due to chance, as the average number of injuries per team per season was no more than 13, assuming an equal distribution between teams. Correcting for variability between teams and clustering effects (that players within teams may be more alike than between teams), as we have done with the GEE model, may therefore represent an overly conservative approach.

The injury incidence of acute match and training injury is still lower in Norwegian male professional football compared to other professional leagues in Europe (Hawkins and Fuller, 1999; Hägglund et al., 2005b; Waldén et al., 2005b; Hägglund et al., 2009; Ekstrand et al., 2011c). In Paper I we showed that medical staff reporting failed to capture about 20% of all time-loss injuries in Norwegian professional football. However, we would expect that there is underreporting in other studies, as well, and even if we underestimated match injury incidence by 20%, it would still be lower than other studies (25.9 to 34.8 injuries/1000 player-match hours) (Hawkins and Fuller, 1999; Hägglund et al., 2005b; Waldén et al., 2005b; Ekstrand et al., 2011c). Waldén et al. (2011a) have categorized teams after the Köppen-Geiger climate classification system and found a higher incidence of severe injuries and training injuries and a lower rate of ACL injuries in Northern parts of Europe, suggesting that there are regional differences in injury incidence in Europa. Our findings show a low rate of ACL injuries in Norwegian football. Also the overall injury incidence and incidence of severe injuries are lower in Norwegian football compared to results from the Champions League.

Why has the match injury incidence increased?

Dupont et al. (2010) followed 32 football players playing in the UEFA Champions league for two seasons to evaluate the effects of playing two matches per week. They found that the recovery time was sufficient to maintain the level of physical performance, but the injury rate was significantly increased when playing two matches per week. However, following one team over 26 days with 8 matches, no difference were detected when comparing to a similar period with fewer matches (Carling et al., 2012). Thus, the effect of match congestion on injury risk needs to be addressed in future studies. During the study period the Norwegian league was a double round robin competition with home and away matches between 14 teams, played from April throughout October, resulting in each team playing a total of 26 league matches, or an average of

3.7 matches per month. In contrast, the English league runs over 9 months (August-May), and consists of 20 teams, giving an average of 4.2 matches per month. In addition, few Norwegian teams participated in European Cups (Champions League and UEFA cup). As the Norwegian league ended late October, many of the European cup games were played "off-season", therefore not increasing the monthly match rate. Thus, players in the Norwegian league play a lower number of games than players at the Champions League level, and other European leagues. Moreover, the number of match hours per club was fairly stable over the study period. A limitation of the Norwegian injury surveillance system is that exposure data is only collected on a team basis, i.e. the total number of players present during each practice. We are therefore not able to test whether the total load (number of games) per player has increased during the study period, nor are we able to examine potential risk factors for the onset of overuse injuries leading to absence from training or match for each player. It has been recommended that exposure is recorded on an individual basis (Fuller et al., 2006).

A report from the Institute for Research in Economics and Business Administration showed that the percentage of foreigners playing professionally in Norway increased gradually from 2000 to 2006 (2000: 15%, 2002: 22%, 2006: 35%) (Gammelsæter and Jacobsen, 2007). It is a possibility that this globalization of the Norwegian league not only has affected the level of play, but also the style of play.

The proportion of match hours on artificial turf was 26% in the 2006 and 2007 season, and if the increased risk seen in match injuries found in Paper II were solely due to the introduction of artificial turf, the injury incidence on artificial turf would have had to be about 33 injuries/1000 player-match hours. In contrast, our data suggest that the match injury incidence was 17.6 (95% CI: 14.7-20.5) on artificial turf (Paper III), thus excluding artificial turf as the explanation for the increased risk of match injuries found in Norwegian professional football.

Injury pattern

About half of all injuries sustained by Norwegian professional players resulted in absence from football activity for one week or less is in accordance with other studies (Ekstrand and Gillquist, 1983; Hägglund et al., 2005b; Ekstrand et al., 2011c). The predominant injury type was muscle injuries (46%), followed by joint injuries (27%) and contusions (14%). Despite finding a lower incidence of match and training injuries, the injury pattern found in our study is in accordance with previous studies at a comparable level of play and we could not detect any substantial changes during the study period. The proportion of re-injuries was approximately 20% of all injuries; this is in accordance with previous studies (Waldén et al., 2005a; Hägglund et al., 2006).

We found that about 30% of all injuries were overuse injuries and that the rate remained constant during the study period. This is in correspondence with previous studies from elite and professional football where the proportion of overuse injuries ranged from 9% to 39% (Waldén et al., 2005b; Arnason et al., 1996; Ekstrand et al., 2011c). Recent studies have showed that standard injury surveillance systems are not suitable for capturing overuse problems as few of the problems recorded led to absence from activity (Clarsen et al., 2010; Clarsen et al., 2012). Thus, the prevalence of overuse injuries is underestimated.

The injury risk during the preseason vs. the competitive season

Previous studies from outside Scandinavia (Hawkins and Fuller, 1999; Ekstrand et al., 2011c) have shown an increased incidence of overuse injuries during the preseason, and a lower incidence of traumatic training injuries during the preseason. In contrast, a Swedish study found an increased incidence of training injuries during the preseason (Waldén et al., 2005a). We were not able to detect any differences in the injury risk between the preseason and the competitive season for acute match injuries (RR: 0.86, 95% CI: 0.73 to 1.01), acute training injuries (RR: 1.16, 95% CI: 0.99 to 1.36) or overuse injuries (RR 1.04 95% CI: 0.89 to 1.21). We found a significantly higher incidence of acute injuries with moderate severity and acute knee injuries during preseason training (Table 7). The incidence of mild acute match injuries was higher during the competitive season.

It must be noted that the league system in Norway and Sweden is different compared to most European leagues. Due to climatic conditions, the Norwegian and Swedish leagues start in April and end in October/November, with a 3 month preseason period starting in January. Most other European leagues have a 4- to 6-week preparation period. Thus, the preseason in other European leagues may be more intense and strenuous, with a correspondingly higher injury incidence. In addition, the coaching, fitness and medical staff in Norway have a longer period to get the players match fit, with the possibility for an increased focus on individual adjustments.

Table 7. Characteristics of injuries sustained during the preseason and competitive season. The incidences are reported per 1000 h of exposure with 95% confidence intervals. Rate ratios between injuries on preseason and competitive season are shown with 95% confidence intervals, with the competitive season as the reference group.

	Pre-season		Competitive season		Preseason vs. competitive season
	Injuries	Incidence	Injuries	Incidence	Rate ratio
Acute match injuries (n=969)					
Injury type					
Fracture	13	1.0 (0.5-1.6)	50	1.0 (0.7-1.3)	0.97 (0.56-1.90)
Muscle and tendon	43	3.3 (2.3-4.3)	234	4.9 (4.2-5.5)	0.69 (0.50-0.95)
Joint and ligament	71	5.5 (4.2-6.8)	246	5.1 (4.5-5.7)	1.08 (0.83-1.40)
Contusions	38	2.9 (2.0-3.9)	187	3.9 (3.3-4.4)	0.76 (0.54-1.08)
Body location					
Groin	6	0.5 (0.1-0.8)	52	1.1 (0.8-1.4)	0.43 (0.19-1.00)
Thigh	45	3.6 (2.5-4.5)	176	3.6 (3.1-4.2)	0.96 (0.76-1.45)
Knee	29	2.2 (1.4-3.1)	122	2.5 (2.1-3.0)	0.88 (0.75-1.69)
Ankle	47	3.6 (2.6-4.7)	130	2.7 (2.2-3.2)	1.35 (0.97-1.88)
Time loss					
1 to 7 days	77	6.0 (4.6-7.3)	394	8.2 (7.4-9.0)	0.73 (0.57-0.93)*
8 to 21 days	65	5.0 (3.8-6.3)	228	4.7 (4.1-5.3)	1.07 (0.81-1.40)
>21 days	39	3.4 (2.1-4.0)	166	3.4 (2.9-4.0)	0.88 (0.62-1.24)
Acute training injuries (n=655)					
Injury type					
Fracture	10	0.1 (0.0-01)	23	0.1 (0.1-0.1)	0.89 (0.42-1.86)
Muscle and tendon	90	0.8 (0.6-0.9)	160	0.7 (0.6-0.8)	1.15 (0.89-1.48)
Joint and ligament	87	0.8 (0.6-0.9)	161	0.7 (0.6-0.8)	1.10 (0.85-1.43)
Contusions	37	0.3 (0.2-0.4)	57	0.2 (0.2-0.3)	1.32 (0.88-2.00)
Body location					
Groin	16	0.1 (0.1-0.2)	28	0.1 (0.1-0.2)	1.17 (0.63-2.15)
Thigh	63	0.5 (0.4-0.7)	117	0.5 (0.4-0.6)	1.10 (0.81-1.49)
Knee	49	0.4 (0.3-0.5)	68	0.3 (0.2-0.4)	1.47 (1.02-2.12)*
Ankle	40	0.3 (0.2-0.5)	84	0.4 (0.3-0.4)	0.97 (0.66-1.41)
Time loss					
1 to 7 days	102	0.9 (0.7-1.1)	232	1.0 (0.9-1.1)	0.89 (0.71-1.13)
8 to 21 days	80	0.7 (0.5-0.9)	101	0.4 (0.3-0.5)	1.61 (1.20-2.17)*
>21 days	56	0.5 (0.4-0.6)	84	0.4 (0.3-0.4)	1.36 (0.97-1.91)
Overuse injuries (n=701)					
Injury type					
Muscle and tendon	190	1.1 (1.0-1.3)	340	1.0 (0.9-1.2)	1.09 (0.91-1.30)
Joint and ligament	15	0.1 (0.0-0.1)	51	0.2 (0.1-0.2)	0.57 (0.32-1.02)
Body location					
Groin	59	0.4 (0.3-0.4)	94	0.3 (0.2-0.3)	1.22 (0.88-1.69)
Thigh	34	0.2 (0.1-0.3)	71	0.2 (0.2-0.3)	0.93 (0.62-1.40)
Knee	40	0.2 (0.2-0.3)	71	0.2 (0.2-0.3)	1.11 (0.74-1.61)
Ankle	37	0.2 (0.2-0.3)	74	0.2 (0.2-0.3)	0.97 (0.66-1.44)
Time loss					
1 to 7 days	127	0.8 (0.6-0.9)	259	0.8 (0.7-0.9)	0.95 (0.77-1.18)
8 to 21 days	71	0.4 (0.3-0.5)	105	0.3 (0.3-0.4)	1.32 (0.97-1.78)
>21 days	46	0.3 (0.2-0.4)	93	0.3 (0.2-0.3)	0.96 (0.68-1.37)

** Significant difference in injury incidence between the preseason and the competitive season*

Risk of injury on third generation artificial turf (Paper III)

From the 2004 season, the injury surveillance system included information on exposure to artificial turf and the playing surface on which injuries were sustained. We found no difference in the overall incidence of injury between grass and artificial turf (RR: 1.01, 95% CI 0.87 to 1.15). However, when comparing the injury incidence between the two surfaces, the difference in exposure on the two surfaces is confounded by the match to training factor. The proportion of match exposure is higher on natural grass compared to artificial turf; in addition, injuries are more common during matches. However, we found no difference between grass and artificial turf during matches (RR: 1.04, 95% CI 0.86 to 1.25), nor during training (RR: 1.07, 95% CI 0.87 to 1.32). This is in accordance with previous studies comparing the risk of injury on third generation artificial turf to natural grass (Ekstrand et al., 2006; Fuller et al., 2007b; Fuller et al., 2007a; Steffen et al., 2007; Soligard et al., 2012; Aoki et al., 2010; Ekstrand et al., 2011a). In contrast, a recent study from Swedish and Norwegian football found an increased risk of training and overuse injuries among clubs with artificial turf on their home venue (Kristenson et al., 2013a).

We could not observe any significant differences in injury incidence between grass and artificial turf for match or training injuries in any of the subcategories of injury location, severity or injury type (table 8). However, we did observe a trend towards an increased incidence of knee and ankle sprains on artificial turf, albeit only during matches. Ekstrand et al. (2006) found a significant difference and Steffen et al. (2007) a trend towards an increased incidence of ankle sprains on artificial turf. Ekstrand et al. (2006) also saw a trend towards a reduced incidence of muscle injuries on artificial turf; there was no indication of this in our study.

We found a tendency towards an increased incidence of severe injuries on artificial turf; however, we used different severity categories than the consensus statement (Fuller et al., 2006). Studies from professional and youth football found a tendency towards an increased incidence of severe injuries on artificial turf (Ekstrand et al., 2006; Steffen et al., 2007). In contrast, Fuller and co-workers (2007), found no significant difference in severity, nature or cause of injuries between natural grass and artificial turf.

Table 8. Characteristics of acute match and training injuries on grass and artificial turf. The incidences are reported per 1000 h of exposure (with 95% CI). Rate ratios between injuries on grass and artificial turf are shown with 95% CI, with grass as the reference group.

	Grass		Artificial turf		Artificial turf vs. grass
	Injuries	Incidence	Injuries	Incidence	Rate ratio
Acute match injuries (n=668)					
Injury type					
Fracture	34	1.1 (0.7-1.5)	7	0.9 (0.2-1.5)	0.79 (0.35-1.78)
Sprain	165	5.3 (4.5-6.1)	57	7.1 (5.2-8.9)	1.33 (0.98-1.79)
Strain	157	5.1 (4.3-5.9)	36	4.5 (3.0-5.9)	0.88 (0.61-1.27)
Contusion	119	3.8 (3.2-4.5)	32	4.0 (2.6-5.4)	1.03 (0.70-1.53)
Cut	12	0.4 (0.2-0.6)	6	0.7 (0.1-1.3)	1.92 (0.72-5.12)
Nervous system	26	0.8 (0.5-1.2)	3	0.4 (0.0-0.8)	0.44 (0.13-1.47)
Other	13	0.4 (0.2-0.6)	1	0.1 (-0.1-0.4)	0.30 (0.04-2.26)
Body location					
Head/neck	61	2.0 (1.5-2.5)	9	1.1 (0.4-1.8)	0.57 (0.28-1.14)
Concussion	42	1.4 (0.9-1.8)	5	0.6 (0.1-1.2)	0.46 (0.18-1.16)
Upper extremity	18	0.6 (0.3-0.9)	3	0.4 (0.0-0.8)	0.64 (0.19-2.17)
Trunk	34	1.1 (0.7-1.5)	12	1.5 (0.6-2.3)	1.36 (0.70-2.62)
Lower extremity					
Groin	48	1.6 (1.1-2.0)	11	1.4 (0.6-2.2)	0.88 (0.46-1.70)
Thigh	107	3.5 (2.8-4.1)	31	3.9 (2.5-5.2)	1.11 (0.75-1.66)
Knee	83	2.7 (2.1-3.3)	26	3.2 (2.0-4.5)	1.20 (0.78-1.87)
Calf	64	2.1 (1.6-2.6)	10	1.2 (0.5-2.0)	0.60 (0.31-1.17)
Ankle	86	2.8 (2.2-3.4)	30	3.7 (2.4-5.1)	1.34 (0.89-2.03)
Foot	25	0.8 (0.5-1.1)	10	1.2 (0.5-2.0)	1.54 (0.74-3.20)
Time loss					
1 to 7 days	263	8.5 (7.5-9.5)	64	8.0 (6.0-9.9)	0.94 (0.71-1.23)
8 to 21 days	151	4.9 (4.1-5.7)	39	4.8 (3.3-6.4)	0.99 (0.70-1.41)
>21 days	112	3.6 (3.0-4.3)	39	4.8 (3.3-6.4)	1.34 (0.93-1.93)
Acute training injuries (n=399)					
Injury type					
Fracture	13	0.1 (0.0-0.1)	5	0.1 (0.0-0.1)	0.90 (0.32-2.53)
Sprain	114	0.7 (0.6-0.9)	43	0.6 (0.5-0.8)	0.88 (0.62-1.26)
Strain	101	0.6 (0.5-0.8)	52	0.8 (0.6-1.0)	1.21 (0.86-1.69)
Contusion	34	0.2 (0.1-0.3)	21	0.3 (0.2-0.5)	1.45 (0.84-2.49)
Cut	1		0		
Nervous system	4		2		
Other	7		2		
Body location					
Head/neck	8		1		
Concussion	6		1		
Upper extremity	16	0.1 (0.1-0.2)	5	0.1 (0.0-0.1)	0.73 (0.27-2.00)
Trunk	19	0.1 (0.1-0.2)	10	0.2 (0.1-0.2)	1.23 (0.57-2.65)
Lower extremity					
Groin	21	0.1 (0.1-0.2)	10	0.2 (0.1-0.2)	1.12 (0.53-2.37)
Thigh	74	0.5 (0.4-0.6)	35	0.6 (0.4-0.7)	1.11 (0.74-1.66)
Knee	52	0.3 (0.2-0.4)	27	0.4 (0.3-0.6)	1.22 (0.76-1.94)
Calf	22	0.1 (0.1-0.2)	10	0.2 (0.1-0.2)	1.07 (0.50-2.25)
Ankle	52	0.3 (0.2-0.4)	21	0.3 (0.2-0.5)	0.95 (0.57-1.57)
Foot	10	0.1 (0.0-0.1)	6	0.1 (0.0-0.2)	1.41 (0.51-3.87)
Time loss					
1 to 7 days	152	1.0 (0.8-1.1)	50	0.8 (0.5-1.0)	0.77 (0.56-1.06)
8 to 21 days	74	0.5 (0.4-0.6)	45	0.7 (0.5-0,9)	1.43 (0.98-2.06)
>21 days	48	0.3 (0.2-0.4)	30	0.5 (0.3-0.6)	1.47 (0.93-2.31)

Video analysis of situations with a high propensity for injury in Norwegian male professional football; a comparison between 2000 and 2010 (Paper IV)

The aim of this study was to compare the rate of high-risk injury incidents between the 2000 and 2010 seasons in Norwegian male professional football, and to compare duel characteristics between the two seasons. We observed a higher rate of both opponent-to-player contact incidents and non-contact incidents in the 2010 season. No difference was observed in the rate of incidents caused by teammate-to-player contact or ball-to-player contact (Table 9).

Table 9. Characteristics of incidents (n=1 287) from video analysis of all games (n=414). Rate is reported as the number of incidents per 1000 player-match hours with 95% confidence intervals (CI). Rate ratios between the 2000 and 2010 seasons are shown with 95% CI, with the 2000 season as the reference group.

	2000		2010		2000 vs. 2010
	Incidents	Rate	Incidents	Rate	Rate ratio
Contact opponent	353	62.7 (56.1-69.2)	734	92.7 (86.0-99.4)	1.48 (1.30-1.68)
Contact teammate	18	3.2 (1.7-4.7)	28	3.5 (2.2-4.8)	1.11 (0.61-2.00)
Non-contact	29	5.1 (3.3-7.0)	68	8.6 (6.5-10.6)	1.67 (1.08-2.58)
Contact ball	17	3.0 (1.6-4.5)	32	4.0 (2.6-5.4)	1.34 (0.74-2.41)
Other	2	0.4 (-0.1-0-8)	6	0.8 (0.2-1.4)	2.13 (0.43-10)

Tackling and heading characteristics

Table 10. Characteristics of head incidents due to opponent-to-player contact from video analysis of all games (n=414). Rate is reported as the number of incidents per 1000 player-match hours with 95% CI. Rate ratios between incidents in the 2000 and 2010 seasons are shown with 95% CI, with the 2000 season as the reference group.

	2000		2010		2000 vs. 2010
	Incidents	Rate	Incidents	Rate	Rate ratio
Duel type					
Heading duel	87	15.4 (12.2-18.7)	215	27.1 (23.5-30.8)	1.76 (1.37-2.26)
Tackling duel	202	35.9 (30.9-40.8)	437	55.2 (50.0-60.4)	1.54 (1.30-1.82)
Other duel	64	11.4 (8.6-14.1)	82	10.4 (8.1-12.6)	0.91 (0.66-1.26)
Body location					
Head/neck	100	17.8 (14.3-21.2)	226	28.5 (24.8-32.3)	1.61 (1.27-2.03)
Upper extremity	8	1.4 (0.4-2.4)	16	2.0 (1.0-3.0)	1.42 (0.61-3.32)
Trunk	41	7.3 (5.1-9.5)	91	11.5 (9.1-13.9)	1.58 (1.09-2.28)
Lower extremity					
Thigh	12	2.1 (0.9-3.3)	39	4.9 (3.4-6.5)	2.31 (1.21-4.42)
Knee	26	4.6 (2.8-6.4)	49	6.2 (4.5-7.9)	1.34 (0.83-2.16)
Lower leg/ankle	166	29.5 (25.0-34.0)	313	39.5 (35.1-43.9)	1.34 (1.11-1.62)
All head situations (n=326)					
Head-to-head	46	8.2 (5.8-10.5)	74	9.3 (7.2-11.5)	1.14 (0.79-1.65)
Arm-to-head	35	6.2 (4.2-8.3)	109	13.8 (11.2-16.3)	2.22 (1.51-3.24)
Shoulder-to-head	2	0.4 (-0.1-0.8)	10	1.3 (0.5-2.0)	3.56 (0.78-16)
Trunk-to-head	1	0.2 (-0.2-0.5)	10	1.3 (0.5-2.0)	7.11 (1 (0.91-55)
Leg-to-head	15	2.7 (1.3-4.0)	21	2.7 (1.5-3.8)	1.00 (0.51-1.93)

We found a higher rate of incidents caused by opponent-to-player contact, both for heading and tackling duels in the 2010 season. We also found a higher rate of head, trunk, thigh and lower leg/ankle contact incidents in the 2010 season (Table 10), as well as an increased incidence of arm-to-head incidents in the 2010 season. No differences were found in the incidence of head incidents caused by other mechanisms.

We found an increased incidence of tackles from all directions, all tackling modes, and one-footed tackles. There was an increase in tackles having contact with the ball prior to player impact and tackles with no ball contact prior to player impact. However, we found no difference in the incidence of two-footed tackles.

Referee decision

We found no differences in the referee decision or sanctions of foul play between the two seasons. We had no referee panel for the referees' decisions during matches; thus, we were not able to assess whether the decision called by the referee was correct according to expert opinion. After the 2000 season, the referees' decisions were reviewed retrospectively by a Norwegian FIFA referee panel, concluding that the judgments of the match referee were according to the existing interpretation of the Laws of the Game. It was noted, however, that there might be a need for an improvement of the laws in order to protect the players from dangerous play (Andersen et al., 2004b).

Player-to-player contact situations

The observed increase in incidents from the 2000 season to the 2010 season could have been due to an increased incidence of player-to-player contacts during each match in the 2010 season. Therefore, we analyzed one home match and one away match for each team participating in the two seasons, 14 games from the 2000 season and 16 games from the 2010 season (Table 11).

Table 11. Characteristics of player-to-player contact situations (n=3 526) from video analysis of 30 randomly picked matches. Situations rate is reported per 1000 player-match hours with 95% CI. Rate ratios between the 2000 and 2010 seasons are shown with 95% CI, with the 2000 season as the reference group.

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

We found that the overall incidence of player-to-player contact was lower in the 2010 season compared to the 2000 season, including the incidences of tackling and heading duels. Thus, the increase in the rate of incidents was not due to a general increase in number of situations with player to opponent contact, but must result from a difference in dueling behavior, i.e. a rougher style of play with more aggressive dueling technique.

Previous studies on injury mechanisms in football have found that most ankle and head injuries are caused by player-to-player contact (Giza et al., 2003; Andersen et al., 2004c; Andersen et al., 2004a). For ankle injuries, the most common cause of contact injury is being tackled to the weight-bearing limb, involving lateral and medial forces and the tackler staying on his feet (Giza et al., 2003; Fuller et al., 2004c; Andersen et al., 2004c). The most common causes of head injuries and incidents are typically heading duels, arm-to-head contact, followed by head-to-head contact (Andersen et al., 2004a). It is therefore a concern that we found an increased rate of duel incidents, and that the increased frequency of head incidents was a result of increased arm-to-head contact.

Stricter rule enforcement – lower incidence of arm-to-head contact incidents (Paper V)

This is the first study to evaluate the effect of changes in the interpretation of the Laws of the game on the risk of injury in male professional football. We were not able to detect any difference in the overall incident rate between the two seasons (Table 12).

Table 12. Characteristics of incidents (n=1721) from video analysis of all games (n=240 each season). Rate is reported as the number of incidents per 1000 player-match hours with 95% confidence intervals (CI). Rate ratios between the 2010 and 2011 seasons are shown with 95% CI, with the 2010 season as the reference group.

	2010		2011		2010 vs. 2011
	Incidents	Rate	Incidents	Rate	Rate ratio
Contact opponent	734	92.7 (86.0-99.4)	687	86.7 (80.3-93.2)	0.94 (0.84-1.04)
Contact teammate	28	3.5 (2.2-4.8)	28	3.5 (2.2-4.8)	1.00 (0.59-1.69)
Non-contact	68	8.6 (6.5-10.6)	91	11.5 (9.1-13.9)	1.34 (0.98-1.83)
Contact ball	32	4.0 (2.6-5.4)	45	5.7 (4.0-7.3)	1.41 (0.89-2.21)
Other	6	0.8 (0.2-1.4)	2	0.3 (-0.1-0.6)	0.33 (0.07-1.65)

Heading and tackling characteristics

We found a reduced frequency of contact head incidents (Table 13); subsequently we found a lower incidence of arm-to-head contact incidents after the implementation of stricter rule enforcement (Table 14). No differences were found in the incidence of other mechanisms for all head incidents or during heading duels.

Table 13. Characteristics of incidents due to opponent-to-player contact (n=1421) from video analysis of all games (n=240 each season). Incident rate is reported per 1000 player-match hours with 95% CI. Rate ratios between the 2010 and 2011 seasons are shown with 95% CI, with the 2010 season as the reference group.

	2010		2011		2010 vs. 2011
	Incidents	Rate	Incidents	Rate	Rate ratio
Duel type					
Heading duel	215	27.1 (23.5-30.8)	177	22.3 (19.1-25.6)	0.82 (0.68-1.00)
Tackling duel	437	55.2 (50.0-60.4)	424	53.5 (48.4-58.6)	0.97 (0.85-1.11)
Other duel	82	10.4 (8.1-12.6)	86	10.9 (8.6-13.2)	1.05 (0.78-1.42)
Body location					
Head/neck	226	28.5 (24.8-32.3)	184	23.2 (19.9-26.6)	0.81 (0.67-0.99)
Upper extremity	16	2.0 (1.0-3.0)	16	2.0 (1.0-3.0)	1.00 (0.50-2.00)
Trunk	91	11.5 (9.1-13.9)	108	13.6 (11.1-16.2)	1.18 (0.90-1.57)
Lower extremity					
Thigh	39	4.9 (3.4-6.5)	56	7.1 (5.2-8.9)	1.44 (0.95-2.16)
Knee	49	6.2 (4.5-7.9)	39	4.9 (3.4-6.5)	0.80 (0.52-1.21)
Lower leg/ankle	313	39.5 (35.1-43.9)	284	35.9 (31.7-40.0)	0.91 (0.77-1.07)

Previous studies on injury mechanisms in football have showed that most head injuries occurs in heading duels, with subsequent arm-to-head contact or head-to-head contact (Andersen et al., 2004a; Fuller et al., 2004c). Incidents and injuries caused by head-to-head contact are normally not deliberate, while arm-to-head incidents sometimes are. Thus, it is encouraging that we were able to detect a reduced rate of arm-to-head contact incidents after the introduction of stricter rule enforcement, explicitly sanctioning intentional high elbows with an automatic red card.

Table 14. Characteristics of head incidents due to opponent-to-player contact (n=410) from video analysis of all games (n=240 each season). Rate is reported per 1000 player-match hours with 95% CI. Rate ratios between the 2010 and 2011 seasons are shown with 95% CI, with the 2010 season as the reference group.

	2010		2011		2010 vs. 2011
	Incidents	Rate	Incidents	Rate	Rate ratio
All head incidents (n=410)					
Head-to-head	74	9.3 (7.2-11.5)	70	8.8 (6.8-10.9)	0.95 (0.68-1.31)
Arm-to-head	109	13.8 (11.2-16.3)	79	10.0 (7.8-12.2)	0.72 (0.54-0.97)
Shoulder-to-head	10	1.3 (0.5-2.0)	11	1.43 (0.65-2.2)	1.10 (0.47-2.59)
Trunk-to-head	10	1.3 (0.5-2.0)	7	0.9 (0.2-1.5)	0.70 (0.27-1.84)
Leg-to-head	21	2.7 (1.5-3.8)	16	2.0 (1.0-3.0)	0.76 (0.40-1.46)
Other-head	2	-	1	-	-
Heading duel (n=286)					
Head-to-head	68	8.6 (6.5-10.6)	66	8.3 (6.5-10.3)	0.97 (0.69-1.36)
Arm-to-head	84	10.6 (8.3-12.9)	47	5.9 (4.2-7.6)	0.56 (0.39-0.80)
Shoulder-to-head	6	0.8 (0.2-1.4)	3	0.4 (0.0-0.8)	0.50 (0.13-2.00)
Trunk-to-head	2	0.3 (-0.1-0.6)	4	0.5 (0.0-1.0)	2.00 (0.37-10)
Leg-to-head	3	0.4 (0.0-0.8)	2	0.3 (-0.1-0.6)	0.67 (0.11-4.00)
Other head	0	-	1	-	-

We found a reduced incident rate of passive tackles from the front (RR 0.76, 95% CI 0.59 to 0.98). There were no differences for passive tackle actions, tackling mode, tackling timing or tackles with ball contact. Thus, the stricter rule enforcement did not alter player behavior substantially. Correspondingly, we were not able to reduce the rate of lower leg/ankle incidents.

For ankle injuries, the most common cause of contact injury is being tackled to the weight bearing limb, involving lateral and medial forces and the tackler staying on his feet (Giza et al., 2003; Fuller et al., 2004c; Andersen et al., 2004c). Therefore, we focused on the sanctioning of two-foot tackles as well as tackles with excessive force with an automatic red card. Still, we found no difference in characteristics for passive tackles between the two seasons, indicating that the intervention did not change player behavior in these incidents. Correspondingly, we were not able to reduce the rate of lower leg/ankle incidents.

Decision of the referee

An important part of this study was the decision of the referees. Did they award free kicks and sanctions as intended, with a straight red card for two-foot tackles, tackles with excessive force and intentional high elbows? The referee decisions are characterized in table 15.

Table 15.Referee decision for different incident types caused by opponent-to-player contact from video analysis of all games (n=240 each season). Proportions were compared using a χ2 test.

	2010		2011		2010 vs. 2011
	Incidents	Percentage	Incidents	Percentage	p-value
Opponent-to-player contact (n=1421)					
Free kick	379	52%	367	53%	0.50
Sanctioned	128	34%	114	31%	0.38
Passive tackling incidents (n=724)					
Free kick	253	67%	262	76%	0.01
Sanctioned	108	43%	103	39%	0.44
Arm-to-head contact (n=188)					
Free kick	38	35%	30	38%	0.66
Sanctioned	6	16%	4	13%	0.89
Arm-to-head contact in heading duels (n=131)					
Free kick	34	41%	17	36%	0.63
Sanctioned	5	15%	1	6%	0.36

Despite a lower incidence of head incidents and no change in the incidence of ankle incidents, we found that a free-kick was awarded in a higher proportion of the passive tackling incidents in the 2011 season. However, no difference was found in the sanctioning of the incidents. We also found that all straight red cards (4) awarded in the 2010 and 2011 season were given for tackling incidents and no straight red cards were given for arm-to-head contact. This might indicate that it is more difficult for the referees to recognize arm-to-head incidents and that the reduction in head incidents and arm-to-head incidents was due to changes in player behavior. Since the 2006 season, the fourth official has become an integral part of the officiating team and the role is to advise the match referee. In recent tournaments, UEFA has introduced two goal-line officials to ensure that the Laws of the Game are upheld, especially within the penalty box. This expansion of the refereeing team may help to ensure stricter rule enforcement.

In an assessment of player error as an injury causation factor in international football it was found that human error during tackling, inadequacies in the Laws of the Game and/or their application by match referees were equally responsible for the high levels of injury observed (Fuller et al., 2004b). In a study of psychological characteristics of football players Junge et al. (2000) found that players have insufficient respect for the Laws of the Game and its regulation. In addition, nearly all players were ready to commit a “professional foul” if necessary and a majority stated that concealed fouls were a part of the game. However, we have not evaluated player attitudes to stricter rule enforcement, but it is possible that the increased focus on the potential of injury through arm-to-head contact and the stricter rule enforcement have changed their attitude towards safer behavior in heading duels.

Player-to-player contact situations

We conducted a separate video analysis where 32 games were analyzed for all situations involving opponent contact. In this analysis we found no difference in the overall incidence of player-to-player contact between the two seasons. We could not detect any difference in the incidence of heading or tackling duels, nor the incidence of arm-to-head contact in heading duels. Thus, there is no reason to assume that the reduced incidence of head incidents and head incidents caused by arm-to-head contact was due to an overall change in the style of play or intensity of matches from the 2010 to the 2011 season.

Injury registration

We found no difference in the overall match injury incidence, contact injury incidence or non-contact injury incidence between the 2010 season and the 2011 season. We found a reduced rate of acute contact injuries of minimal severity. No difference was detected between the two seasons for injury type and injury location.

General methodological considerations

A strength of Paper I is the participation rate, 13 of 14 clubs participated and 296 of 310 (96%) of the players were interviewed, leading to a high validity of the study. Paper II and III include a high number of time-loss injuries, thus reducing the risk of type II errors. Nevertheless, there still is a possibility of a type II error resulting from limited data, especially when comparing the incidences in subcategories of injuries and incidents (e.g. for a specific injury location, type or severity). Another strength of Paper II and III is the validation of the injury registration method. The medical staff of Norwegian professional clubs fails to report about 20% of all time-loss injuries. However, no difference related to surface when the injury was sustained, injury type, severity, nor body part was detected. Thus, although the overall injury incidence in Paper II and Paper III is probably underestimated, but is unlikely to have interfered with our comparison of subcategories.

A weakness of our injury surveillance system is the limited information about injury risk factors and injury mechanisms. This combined with the lack of individual exposure data limits our ability to assess whether there have been any changes in the causes of injuries over the study period. We are therefore not able to adjust for the two main factors contributing to surface-related injuries; the hardness of the playing ground and the shoe-surface traction (Nigg and Yeadon, 1987).

As mentioned above, the current set-up of the injury surveillance system, using a “time-loss”-definition, leads to an underestimation of the prevalence and incidence of overuse injuries (Bahr, 2009). Therefore, we cannot exclude that the incidence of overuse or acute injuries not leading to time loss from matches or training has increased (Paper II). Secondly, overuse injuries are defined as being the result of repeated micro-trauma without a single, identifiable event responsible for the injury (Fuller et al., 2006). Therefore, even if a “physical complaint”-definition were used, an overuse injury cannot be attributed to one specific training session or match and, hence, to one of the two turf types in question in Paper III.

A possible limitation of Paper IV and Paper V is the video quality. However, during the recent decade the image quality, the number of camera views and the resolution has improved. In the 2000 season 11% of the matches were broadcast using more than three cameras, whereas in the 2010 and 2011 season all games were broadcasted with at least three cameras, making it easier to capture incidents. Thus, the incident rate might have been underestimated in the 2000 season, leading to an overestimation of the difference between the 2000 season and the 2010 season. The 15 s parameter was chosen because that was thought to be long enough to avoid incidents where players intentionally stayed down either to rest, simulate or to delay playing time. Paper IV and V did not include a referee panel to evaluate the decisions of the referees; thus, we are not able to assess whether the decisions were correct according to expert opinion.

Substantial changes in the injury recording methodology were made prior to the 2010 season, as the UEFA Injury Study Protocol was implemented in Norwegian professional football. Thus, a major limitation of Paper IV is that we cannot compare the actual injury rate between the 2000 and 2010 seasons; we therefore do not know if the increase observed in the rate of incidents also can be extrapolated to an increase in injury rate.

A strength of Paper V is the wide support of the study within Norwegian football. All stakeholders in Norwegian football were informed of the stricter interpretation of the rules and all participating parties were thoroughly informed prior to the league start in March 2011.

In Paper V a reduction of contact injuries would ideally serve as end-point. However, with an expected total of 50 contact injuries, the effect of the stricter rule enforcement would have required a 70% decrease in injury incidence in order to detect it. However, only 47 of the 1421 (3%) incidents resulted in an injury recorded by the medical staff. In addition, video analysis did not capture 35 of the injuries recorded by the medical staff. Despite this, we do believe incidents serve as a valid surrogate measure of injury risk, as the incidents represents events with a propensity for injury (Andersen et al., 2004d; Arnason et al., 2004b; Fuller et al., 2004c).

With an RCT not being possible, a pre-/post-intervention design was employed, where data from the 2011 season was compared to 2010 season data. There have been no other changes in the Norwegian male professional league system or style of play that we can think of which could explain the observed reduction in head incidents, or head incidents caused by arm-to-head contact.

Conclusions

I. Prospective injury surveillance by team medical staff in Norwegian male professional football underestimates the incidence of time-loss injuries by at least one-fifth (Paper I).

II. The six-season injury registration documented that the overall incidence of acute match injuries in Norwegian male professional football increased by 6% per year during the study period, although this increase was not fully consistent across teams (Paper II)

III. No significant difference in training or match injury incidence was detected between the preseason and competitive season (Paper II).

IV. No significant differences were detected in injury rate or pattern between third-generation artificial turf and natural grass in Norwegian male professional football (Paper III).

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

VI. We found no significant differences in the overall rate of incidents after the introduction of stricter rule enforcement. However, the rate of head and arm-to-head incidents was lower (Paper V).

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Papers I-V

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Scand J Med Sci Sports 2010
doi: 10.1111/j.1600-0838.2009.01085.x

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Injury surveillance in male professional football; is medical staff reporting complete and accurate?

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Accepted for publication 19 October 2009

Since the 2000 season, an injury surveillance system has been established to monitor injury risk and injury patterns in the Norwegian professional football league. The aim of this study was to assess the accuracy of routine injury registration performed by medical staff in professional football. The team medical staff completed injury registration forms on a monthly basis throughout the 2007 season (January–October). Players were interviewed at the end of the season (October/November) about all injuries that occurred from July through September. Thirteen of fourteen teams, 296 of 310 A-squad players were interviewed. An injury was recorded when a player was unable to take fully part in football training or match the day after injury. A total of 174 injuries were registered, 123 acute injuries and 51 overuse injuries. Of these, 141 were reported by medical staff and 122 by players. Eighty-nine injuries (51%) were registered using both methods, 52 (30%) by medical staff only and 33 (19%) by player interviews only. Prospective injury surveillance by team medical staff in Norwegian male professional football underestimates the incidence of time-loss injuries by at least one-fifth.

Over the last three decades, many different injury definitions and methods have been used to record injuries among football players, leading to a significant discrepancy in the injury incidences reported (Fuller et al., 2006a, b, c), The incidence of time-loss injuries reported from studies in elite football varies from 15.8 to 34.8 per 1000 match hours, and 2.3 to 5.9 per 1000 training hours (Nielsen & Yde, 1989; Arnason et al., 1996; Hawkins & Fuller, 1999; Waldén et al., 2005).

Professional football players are employees, and therefore covered by the same health and safety legislation as other workers (Fuller, 1995). Injury registration is a key risk management tool; injury incidence and patterns must be known to be able to intervene on modifiable risk factors. Injury incidence is not only dependent on the injury definition in use, but the registration method will also have a significant impact on the injury incidence reported (Inklaar, 1994; Dvorak & Junge, 2000; Fuller et al., 2006a, b, c).

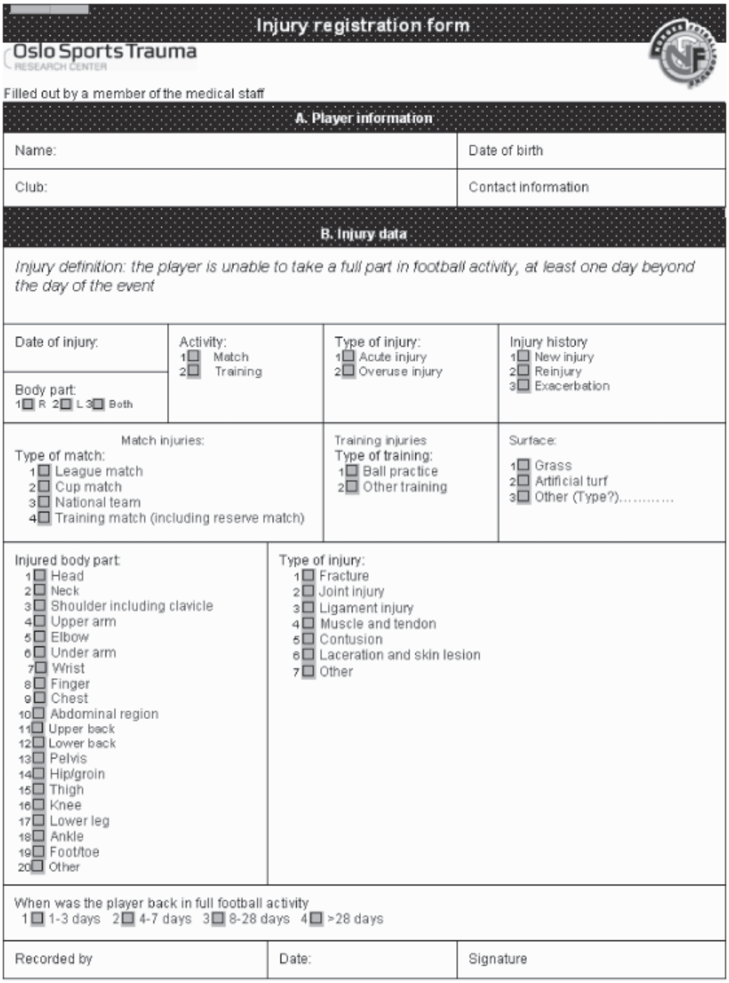
A consensus statement on injury definitions and data-collection procedures for studies of injuries in football from 2006 emphasized that injury registration should be carried out prospectively and conducted by a member of the medical staff (Fuller et al., 2006a, b, c). However, the methodological implications of these recommendations have not been studied previously. The reliability and validity of injury registration has been emphasized as a field that needs further investigation (Hägglund et al., 2005).

A study by Junge and Dvorak (2000) from Czech football found that retrospective interviews only captured 1/3 of what was recorded prospectively by a physician visiting the teams once a week during the season. However, it is not known whether a routine injury surveillance system captures all time-loss injuries suffered by players. We therefore designed this study to compare prospective injury registration by team medical staff with structured, retrospective player interviews.

Materials and methods

Study design and population

The Norwegian male professional league (Tippeligaen) consists of 14 football clubs, representing the highest level of play in Norway among males. As part of a continuous prospective injury registration system that was established in 2000 (Andersen et al., 2004), the medical staff of each club recorded all injuries sustained by players with a first-team contract throughout the 2007 season (January–November) for the prospective part. We invited all players with a first-team contract to participate in the study, but did not include players on trial or youth players without a professional contract. We interviewed the players in October about all injuries that occurred during three of the final months of the season (i.e. from July through September of the same year).



Injury registration form

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Filled out by a member of the medical staff

A. Player information

Name:	Date of birth
Club:	Contact information

B. Injury data

Injury definition: the player is unable to take a full part in football activity, at least one day beyond the day of the event

Date of injury: Body part: 1☐ R 2☐ L 3☐ Both	Activity: 1☐ Match 2☐ Training	Type of injury: 1☐ Acute injury 2☐ Overuse injury	Injury history 1☐ New injury 2☐ Reinjury 3☐ Exacerbation
Match injuries: Type of match: 1☐ League match 2☐ Cup match 3☐ National team 4☐ Training match (including reserve match)		Training injuries Type of training: 1☐ Ball practice 2☐ Other training	Surface: 1☐ Grass 2☐ Artificial turf 3☐ Other (Type?)…………

Injured body part: 1☐ Head 2☐ Neck 3☐ Shoulder including clavicle 4☐ Upper arm 5☐ Elbow 6☐ Under arm 7☐ Wrist 8☐ Finger 9☐ Chest 10☐ Abdominal region 11☐ Upper back 12☐ Lower back 13☐ Pelvis 14☐ Hip/groin 15☐ Thigh 16☐ Knee 17☐ Lower leg 18☐ Ankle 19☐ Foot/toe 20☐ Other	Type of injury: 1☐ Fracture 2☐ Joint injury 3☐ Ligament injury 4☐ Muscle and tendon 5☐ Contusion 6☐ Laceration and skin lesion 7☐ Other

When was the player back in full football activity
1☐ 1-3 days 2☐ 4-7 days 3☐ 8-28 days 4☐ >28 days

Recorded by	Date:	Signature

Fig. 1. Injury form used for both registration methods.

The Regional Committee for Medical Research Ethics, Region Øst-Norge and the Norwegian Social Science Data Services approved the study.

Injury definition and injury form

We used a time-loss definition, in accordance with the consensus statement, when recording injuries; an injury was registered if the player was unable to take full part in football activity or match play at least 1 day beyond the day of injury (Fuller et al., 2006a, b, c). According to the onset of an injury, injuries were defined as acute or overuse, evaluated by the medical staff and the players. If the injury was the result of a specific, identifiable event, it was defined as acute. If the onset was gradual, without a single, identifiable event, it was reported as an overuse injury (Fuller et al., 2006a, b, c). We used the same injury registration form for the medical staff registration and the player interviews. We developed the form according to the consensus statement, including information about the date of injury, the type of activity (match or training) in which the injury occurred, injury location and injury history (Fig. 1). Injuries were categorized into four severity categories according to the duration of absence from match and training sessions: minimal (1–3 days); mild (4–7 days); moderate (8–28 days); and severe (>28 days). Players were defined as injured until they could take full part in first-team football training or match play (Fuller et al., 2006a, b, c).

Injury registration by medical staff

A member of the club medical staff performed the prospective injury registration, in most cases the physiotherapist, but in some cases the team physician. We sent a manual with instructions on how to conduct the injury registration to the medical staff at the start of each season. The club license in Norway requires that a physiotherapist attend each football activity, training and matches. In addition, at least one physician, usually from the home team, must attend all games. Forms were collected on a monthly basis and, if needed, we followed up with reminder text messages and phone calls. We checked the injury cards thoroughly when we received them. If information was missing or any other inconsistencies were seen, a member of the study group contacted the medical staff to resolve this. The team medical staff was kept unaware of the player interview sessions that we planned to conduct after the end of the season.

Player interviews

Most of the clubs were interviewed in October, usually in connection with team training or in the player hotel the day before a match. However, for clubs participating in UEFA

Injury surveillance -player interview
Viking

Oslo Sports Trauma RESEARCH CENTER

Injury defintion: the player was unable to take a full part in football activity at least one day beyond the day of injury

Player name ____________________

Nation ____________________

Contact information ____________________

Week	Date	Site	Activity	Participated: Yes	Injury: Yes	If "yes" on injury, fill out form. Other notes:
		Mid season training	Training	☐	☐	
29	21.07.2007	Rosenborg (A)	☐	☐	☐	
16-22.7			Training	☐	☐	
30	25.07.2007	Brann (H) - cup	☐	☐	☐	
	30.07.2007	Start (H)	☐	☐	☐	
23-29.7			Training	☐	☐	
31	05.08.2007	Sandefjord (A)	☐	☐	☐	
30.7-5.8			Training	☐	☐	
32	12.08.2007	Fredrikstad (H)	☐	☐	☐	
6-12.8			Training	☐	☐	
33	18.08.2007	Odd (A) - cup		☐	☐	
13-19.8			Training	☐	☐	
34	26.08.2007	Odd (A)	☐	☐	☐	
20-26.8			Training	☐	☐	
35	02.09.2007	Lillestrøm (H)	☐	☐	☐	
27.8-2.9			Training	☐	☐	
36				☐	☐	
3-9.9			Training	☐	☐	
37	16.09.2007	Lyn (A)	☐	☐	☐	
10-16.9			Training	☐	☐	
38	23.09.2007	Aalesund (H)	☐	☐	☐	
17-23.9			Training	☐	☐	
39	30.09.2007	Strømsgodset (H)	☐	☐	☐	
24-30.9			Training	☐	☐	

Number of injuries: __________ Number of injury forms: __________

Fig. 2. Example of interview form with a week-by-week schedule. The form was used to facilitate player recall, and for each week, the player was asked "did you participate fully in all first team training sessions during that week?" and "were you selected in the squad for the match?" If no, then he was asked whether that was due to a football-related injury, and if so, an injury form was completed.

competitions after the regular season, we conducted some player interviews during early November. Twelve telephone interviews were carried out with players not present during the team interview sessions. Physicians and medical students from the Oslo Sports Trauma Research Center completed one-on-one interviews based on a structured interview form that was first developed for volleyball (Bahr & Reeser, 2003) and later also used in World Cup skiing (Florenes et al., 2009). The interviewers were blinded to the data from the prospective injury registration. To facilitate player recall, the interviews were based on a week-by-week schedule of each club's training and match program for the three-month study period (Fig. 2). Player interviews were conducted one on one in quiet and private surroundings. The players were asked whether they participated fully in first-team training and were available for match selection each week. They were also asked whether or not they were selected for the match squad. If they did not participate fully in training or were not selected, we asked whether they had an injury during that period. If a player reported an injury, we informed him about how we defined an injury and asked when he was able to participate fully in football training. We completed the same injury registration form as that used by the medical staff registration.

Media monitoring

A member of the study group monitored the homepage of each club, the local newspaper and the match previews in the largest national newspapers prospectively. This was done to double check the information provided in the player interviews and reported by the medical staff. We also checked that players claiming to have been injured did not appear on the match roster during the period in question.

Statistics

Kappa correlation coefficients were calculated for agreement between methods (Altman, 1991). 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 <0.20 as poor (Altman, 1991).

Results are presented by comparing information reported from medical staff with that reported in the retrospective player interviews.

Results

Thirteen of the 14 clubs in Tippeligaen completed the study, while one club had to be excluded because the medical staff had not provided any information before the player interviews. Of 310 eligible players, 296 (95%) were interviewed and included in the study. Of the 14 players not participating in the study, six had language problems, seven players were absent from the training session the day the study group visited the club and did not respond to subsequent phone calls. One player declined the invitation to participate.

During the 3-month study period, 133 (45%) of the players sustained at least one injury, and a total of 174 unique injuries were registered. Of these, 19% were only recorded through the player interviews, 51% by both the interviews and the medical staff registration and 30% only through the medical staff registration (Table 1). All of the injuries reported by the players only corresponded with media reports and match records. Of the 123 acute injuries, 19% were only recorded through the player interviews, 54% by both methods and 28% only through the medical staff registration. Of the 51 overuse injuries, the corresponding figures were 20%, 45% and 35%. The total acute injury incidence reported through medical staff registration was 4.9 injuries per 1000 playing hours and 4.3 through player interviews. The acute match injury incidence was 17.9 vs 16.1; the acute training injury incidence was 2.4 and 2.1, respectively. Of injuries occurring during July, 42% were only recorded by the medical staff (not recalled by players). For the months of August and September, the proportions were 35% and 20%, respectively.

Of the 89 injuries recorded by both methods, 64 (72%) had corresponding severity classifications (Table 2). Of the 33 injuries that were not reported by the medical staff, 16 (49%) were minimal, nine (27%) mild, seven (21%) moderate and one (3.0%) severe. Of the 52 injuries that were reported by the medical staff only, 19 (37%) were minimal, 19 (37%) mild and 14 (27%) moderate.

Of the 89 injuries that were reported by both the medical staff and through player interviews, all but two were reported as the same injury type (Table 3). Injuries to muscle and tendons (both acute and overuse injuries) were the injury types most frequently missed in both the medical staff registration and the athlete interview (67% and 56%, respectively).

When comparing the body part injured as reported by the medical staff with that reported by the athletes, 88 out of 89 injuries were identical (Table 4). The most frequent type of injury missed was thigh injuries, constituting 15 (46%) of the injuries that the medical staff did not report and 15 (29%) of those not reported by the athletes.

When comparing information from the 66 acute injuries reported by both the medical staff and the athletes, 59 (89%) had corresponding information regarding type of activity when the injury was sustained (Table 5). The medical staff reported 100 of the 123 acute injuries identified during the study period; of the 23 injuries missing, nine (39%) were sustained during league matches, three (13%) during training matches (including reserve games) and 11 (48%) during ball practice.

For injuries recorded through both methods, the kappa correlation coefficients for agreement between the medical staff report vs the player interviews were 0.61 (95% CI 0.48–0.74) for injury severity, 0.97 (0.92–1.01) for injury type, 0.99 (0.96–1.01) for body part injured and 0.89 (0.79–0.98) for activity when injured.

Discussion

The aim of this study was to assess the accuracy of a prospective injury registration system based on medical staff reporting by comparing it with retrospective player interviews. The main finding was that medical staff reports underestimated the incidence of time-loss injuries by 19% for the 3-month study period as a whole. The study also showed that 30% of the injuries registered by the medical staff were not reported by the players, indicating that there is a significant recall bias associated with retrospective player interviews. Player recall appeared to deteriorate month by month.

That more injuries are recorded by prospective injury registration compared with retrospective interviews is in accordance with previous studies from football, preschool children and among physical education students (Twellaar et al., 1996; Junge & Dvorak, 2000; Fonseca et al., 2002). Prospective injury registration is not complete, but the reliability of retrospective injury registration is even poorer (Twellaar et al., 1996). Czech football clubs were followed for 1 year by a physician each week to record injuries among their players, and in addition, the players were asked to fill out a questionnaire after the 12-month season (Junge & Dvorak, 2000). They found that there is significant recall bias associated with retrospective player interviews, especially regarding mild injuries sustained close to 1 year in the past (Junge & Dvorak, 2000). In an attempt to minimize the effect of recall bias during the player interviews, we limited the study period to 3 months. However, it should be noted that as some players were not interviewed until mid-November, they had to recall injuries that may have occurred as much as 4.5 months back in time. The period July through September was chosen in order to ensure that the players were available for interviews during the final weeks of the season. The competitive season ended in the beginning of November, and most clubs give their players a 4- to 6-week training holiday after this. In order to optimize the interview, we used a structured format based on the team schedule to facilitate recall and focused on the player–interviewer relationship and interview setting. The players were thoroughly informed about confidentiality and the interviews were conducted one-on-one and in private. Despite these measures, 30% of the injuries reported by team medical staff for the 3-month study period were not recalled by the players.

Table 1. Comparison of injuries recorded through medical staff reports, player interviews or both methods

	Medical staff	Both methods	Player interview
All injuries	52	89	33
July	16	18	4
August	21	28	11
September	15	43	18
Acute injuries	34	66	23
Overuse injuries	18	23	10

Table 2. Comparison of severity information between medical staff reports and player interviews

Medical staff	Player interview					
	1–3 days	4–7 days	8–28 days	>28 days	Not recorded	Total
1–3 days	4	6			19	29
4–7 days	5	17	4		19	45
8–28 days		2	24	6	14	46
>28 days			2	19		21
Not recorded	16	9	7	1		33
Total	25	34	37	26	52	174

Results are shown as the number of cases in each severity category, classified according to the number of days of absence from training and match play.

Table 3. Comparison of injury type classification between player interviews and medical staff reports

Medical staff	Player interview							
	Fracture	Joint/ligament	Muscle/tendon	Contusion	Skin/laceration	Other	Not recorded	Total
Fracture	9							9
Joint/ligament		20	2				13	35
Muscle/tendon			46				29	75
Contusion				9			9	18
Skin/laceration							1	1
Other						3		3
Not recorded	1	2	22	6	1	1		33
Total	10	22	70	15	1	4	52	174

Table 4. Information on localization of injury from player interviews compared with information provided by medical staff

Medical staff	Player interview												
	Head	Neck	Shoulder	Chest	Lower back	Hip-groin	Thigh	Knee	Lower leg	Ankle	Foot	Not recorded	Total
Head	3											1	4
Neck												1	1
Shoulder			1									3	4
Chest				2								1	3
Lower back					5							3	8
Hip-groin						14						4	18
Thigh						1	19					15	35
Knee								13				6	19
Lower leg									10			9	19
Ankle										11		8	19
Foot											10	1	11
Not recorded	2			1	1	5	15	1	4	2	2		33
Total	5	0	1	3	6	20	34	14	14	13	12	52	174

Table 5. Comparison of activity between player interviews and medical staff registration on type of activity when the injury was sustained

Medical staff	Player interview						Total
	League match	Cup match	National team	Training match	Ball practice	Not recorded	
League match	24	2				12	38
Cup match	1	3				2	6
National team			2				2
Training match				7	1	6	14
Ball practice	2			1	23	14	40
Not recorded	9			3	11		23
Total	36	5	2	11	35	34	123

Our study is the first to validate the accuracy of an established injury surveillance system based on registration by regular team medical staff in professional football. In contrast, Junge and Dvorak (2000) had a member of the research group travel to each club each week to register injured players. These data were then, after the end of the season, compared with retrospective interviews. As noted, retrospective player interviews are limited by recall bias, and therefore cannot be used as a "gold standard." Rather, the question was whether players did recall injuries that had not been recorded through the injury surveillance system. Indeed, for the 3-month study period, we found that the medical staff reports underestimated the incidence of time-loss injuries by 19%. Another interesting observation was that player recall deteriorated with time; the proportion of injuries that were only reported through the player interviews increased from July (11%) to September (24%). Therefore, the true injury incidence may be underestimated by more than 24%.

The aim of the study was to examine whether routine injury surveillance produces complete and accurate data. In order to ensure that the medical staff registration was not influenced by prior knowledge of the validation study, our study was introduced to the medical staff and players only after the September injury data had been collected. This was also the first verification of data quality since the injury surveillance system was started in 2000. We therefore believe that the data are representative for the quality that can be expected from day-to-day routine surveillance.

Junge and Dvorak (2000) found that the localization and circumstances of injury were similar in both the prospective and the retrospective data collection. In our case, for injuries captured by both recording methods, the agreement was very good for the categories body part injured, activity when injured and injury type and good for severity. However, as can be seen from Table 2, when there was a discrepancy between the player and the medical staff reports regarding severity, in 16 cases, the player reported a longer absence than the medical staff, while there were only nine cases where medical staff reported longer absence. Certainly, some of this is a problem of recall; we asked players to recall injuries that may have occurred up to 4.5 months ago. Another source of bias may have been the interpretation of when an injured player returned to full participation. According to the injury definition, a player not able to participate fully should be reported as being in rehabilitation, i.e. as injured. In the interviews, we clarified the "fully fit" criterion clearly for the player when recording an injury, and there are certainly cases where the medical team may have cleared a player for full participation but in retrospect the player reported during the interviews that in fact he was not participating fully, at least initially. However, the results show that the main challenge with injury surveillance is to get the medical staff to fill out the injury form in the first place. When they do, the information appears to be correct.

The injury-surveillance manual requires clubs to submit their forms on a monthly basis. In our experience, there are differences between the clubs in their injury registration routines. Some clubs routinely complete the form on the day of injury, while others seem to fill out the forms once a month. Further evidence of this is that 76% of all injuries missed by the medical staff were injuries leading to an absence of less than one week; this indicates a possible recall bias by team medical staff of mild injuries. However, we were also surprised to see seven moderate and one severe injury went unreported by team medical staff. We do not know why these were not recorded, as they were obviously known to the medical team in the club. These injuries were all confirmed by the media monitoring and match records, and we therefore have no reason to believe that they were not genuine. Some clubs have several people involved in the injury registration, and in these cases, it is important to clarify the role and responsibilities of each in the injury surveillance system.

A limitation of the Norwegian injury surveillance system, as well as many epidemiological studies, is that exposure data are only collected on a team basis, i.e. the total number of players present during each practice. It has been recommended that exposure is recorded on an individual basis (Fuller et al., 2006a, b, c). This would allow the study group to control player attendance vs injury reports received, and should serve to increase the capture rate. Media monitoring is another possible source of information. Media often offer preview programs or websites with weekly information about all available and injured players. This media coverage service was used in this study to verify new injuries reported by the players. Faude and colleagues concluded from their study in German professional football that media-based injury statistics were almost complete; however, the diagnosis was not available in all cases.

Another option to improve the capture rate is to use web-based injury surveillance systems, which have been suggested as a solution to ensure the quality of injury registration. One important advantage of these is that the injury-surveillance component can be married to the player's medical record, and even the team schedule and roster. In this way, an injury form can be generated (semi)automatically whenever a patient record is entered into the system. However, it must be underlined that such a surveillance system must take into account the need for strict player confidentiality (Hägglund et al., 2005). An increased focus on medico-legal issues among sports medicine professional will also help to ensure that all patient encounters are recorded. A web-based program may also make it easier for medical staff to record injuries, with no need to bring paper forms, when for example on the road. Barriers include computer and internet access. However, in the near future, this will be less of a problem; increased wireless internet access and new computer devices (e.g. personal digital assistants, advanced cell phones) will facilitate the introduction of web-based recording systems.

Interestingly, medical staff recording is not necessarily the best injury registration method in all settings. A recent study among elite skiers and snowboarders found that only 61% of all recorded injuries were reported by the medical staff, and that only 6% of the injuries were missed by retrospectively player interviews (Florenes et al., 2009). This might be explained by the fact that in winter sports most of the teams and athletes travel continuously during the competitive season. It might therefore be difficult for team medical staff to register and send in injury reports on a regular basis. In contrast, football teams spend most of the week in their own training facilities, with team medical staff in attendance most of the time. Thus, injury registration systems should be tailored to the sports they are intended for, using different methods in different sports depending on the availability of medical staff.

In conclusion, prospective injury surveillance by team medical staff in Norwegian male professional football underestimates the incidence of time-loss injuries at least by one-fifth.

Perspectives

Professional football players are employees, and are therefore covered by the same health and safety legislation as other workers (Fuller, 1995). Injury surveillance is a key risk management tool to monitor injury incidence and injury patterns to ensure the safest possible work environment for the players. Today, injury registration is not compulsory for the clubs and medical staff. Implementation of injury registration as a requirement to be issued a club license by the national football association would ensure that this important risk management tool is in place. The accuracy of an injury surveillance system is the responsibility of the study group; it is therefore important to establish routines for ongoing education of the medical staff involved, regular feedback with injury statistics and close follow-up. During the European Championships, the team doctor is contacted every third day, to obtain a high response rate and clarify reporting procedures (Waldén et al., 2007). In FIFA tournaments, the injury forms are collected after each match by a medical officer of the FIFA-Medical Assessment and Research Centre (Junge et al., 2004). We recommend that daily exposure is recorded for each individual player, as this allows both team medical staff as well as the study group to verify absences and injury reports. Computer-based systems could be programmed to flag discrepancies automatically.

Key words: football, athletic injuries, epidemiology, methodology.

Acknowledgements

We would like to thank the players and the medical staff in Tippeligaen for their participation.

This work was supported by the Medical Student Research Program at the University of Oslo. The Oslo Sports Trauma Research Center has been established at the Norwegian School of Sport Sciences through grants from the Royal Norwegian Ministry of Culture and Church Affairs, the South-Eastern Norway Regional Health Authority, the Norwegian Olympic Committee & Confederation of Sport and Norsk Tipping AS.

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Scand J Med Sci Sports 2012: ••: ••–••
doi: 10.1111/j.1600-0838.2012.01476.x

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MEDICINE & SCIENCE
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Gradual increase in the risk of match injury in Norwegian male professional football: A 6-year prospective study

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Accepted for publication 5 April 2012

The aim of this study was to monitor injury incidence and pattern in Norwegian male professional football over six consecutive seasons and compare the risk of injury between the preseason and competitive season. All time loss injuries were recorded by the medical staff of each club. In total, 2365 injuries were recorded. The incidence of acute injuries was 15.9/1000 match hours [95% confidence interval (CI): 14.9–16.8], 1.9/1000 training hours (95% CI: 1.7–2.0), and 1.4 (95% CI: 1.3–1.5) overuse injuries/1000 h. A linear regression model found an annual increase of 1.06 acute match injuries/1000 h (95% CI: 0.40–1.73), corresponding to a total increase of 49% during the 6-year study period. When accounting for interteam variation and clustering effects using a general estimating equation model, the increase in injury incidence was 0.92 (95% CI: –0.11–1.95, *P* = 0.083). No difference in the risk of acute match injuries (rate ratio (RR): 0.86, 95% CI: 0.73–1.01), acute training injuries (RR: 1.16, 95% CI: 0.99–1.36), or overuse injuries (RR: 1.04, 95% CI: 0.89–1.21) was observed between the preseason and competitive season. In conclusion, the overall risk of acute match injuries in Norwegian male professional football increased by 49% during the study period, although this increase was not fully consistent across teams. We detected no change in the risk of training and overuse injuries or any difference between the preseason and competitive season.

There is an injury risk involved in playing football, and the risk is significantly higher during match play compared to training at all levels of play (Arnason et al., 1996; Andersen et al., 2004c; Walden et al., 2005b; Ekstrand et al., 2010). The match injury incidence in male elite football is 1000 times higher than the injury risk in high-risk industrial occupations (Drawer & Fuller, 2002). Most football injuries have a traumatic onset, with player-to-player contact accounting for 44% to 59% of all acute match injuries at club level (Ekstrand & Gillquist, 1983; Arnason et al., 1996). Overuse injuries account for 9% to 35% of all injuries recorded (Engstrom et al., 1990; Arnason et al., 1996; Hawkins & Fuller, 1999; Walden et al., 2005b; Ekstrand et al., 2010). The injury incidence has been reported to vary over different periods of the season, with peaks during the preseason, the midseason breaks, and intensive match periods (Ekstrand & Gillquist, 1983; Hawkins & Fuller, 1999; Walden et al., 2005b; Ekstrand et al., 2010). Ekstrand et al. (2010) documented an increased risk of overuse injuries and lower risk of traumatic injuries during the preseason.

Few studies have been carried out over several seasons (Hawkins & Fuller, 1999; Hagglund et al., 2006; Ekstrand et al., 2010), which is essential to follow trends in injury incidence and shifts in the injury pattern. Ekstrand et al. (2010) found in their study from the Champions League that the injury incidence and pattern was stable during the seven-season study period.

The aim of this study was to monitor the incidence of injury and injury pattern in Norwegian male professional football over six consecutive seasons. We also wanted to evaluate if there was an increased risk of injury during the preseason compared to the competitive season.

Materials and methods

Study design and population

The study population included players with a first team contract with one of the 14 clubs in the male Norwegian professional league (Tippeligaen). As part of a continuous prospective injury surveillance system established in 2000 (Andersen et al., 2004b), all injuries sustained were recorded by the medical staff in each club. The present study includes data from 2002 throughout the 2007 season (January through October/November). Players on trial or youth players without a professional contract were not included. The preseason went from January throughout March, while the competitive season started primo April and ended in October/November.

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

Injury definition and injury form

We used a time loss definition and injury form in accordance with the consensus statement for recording football injuries (Fuller et al., 2006). An injury was registered if the player was unable to take fully part in football activity or match play at least one day beyond the day of injury. The player was considered injured until declared fit for full participation in training and available for match selection by the medical staff. If the injury was the result of a specific, identifiable event or had a sudden onset, it was defined as acute. If the injury was caused by repeated microtrauma without a single, identifiable event responsible for the injury, it was defined as an overuse injury. Reinjury was defined as an injury of the same type and at the same site as an index injury and which occurred after a player's return to full participation from the previous injury. The injury form included information about the date of injury, the type of activity (match or training) in which the injury occurred, injury location, and injury history. Based on the National Athletic Injury Registration System, injuries were categorized according to the duration of absence from match and training sessions; mild (1–7 days); moderate (8–21 days), and severe (> 21 days; van Mechelen et al., 1992). We classified the injury diagnoses using the Orchard Sports Injury Classification System (Orchard, 1993).

Injury registration by medical staff

A member of the club medical staff, in most cases the physiotherapist, performed the prospective injury registration. We sent a manual with instructions on how to complete the injury and exposure forms to the club medical staff. The club license for Norwegian professional football clubs requires that a chartered physiotherapist is available for the club and they usually attend all organized team activities, i.e., all training sessions and matches. We collected the forms on a monthly basis and, if needed, we followed up with reminder text messages and phone calls. Injury cards submitted were controlled carefully. If information was missing or we discovered any other inconsistencies, a member of the study group contacted the medical staff for clarification. Injuries during national team training and matches were not included.

Exposure registration

We collected exposure data at the team level. The exposure registration form included information about the type and duration of each match or training session, the number of participants, and the surface during the session. Exposure was recorded by a member of the coaching staff or medical staff. Match exposure for players included all matches between teams from different clubs of players with an A-squad contract. Training exposure was defined as any physical activity carried out under the guidance of a member of the first team coaching staff. Exposure during national team training and matches was not included.

Statistics

Results are presented as injury incidence (injuries/1000 h of exposure) in training and match play. The overuse injury incidence was calculated with total exposure time as the denominator. We used a *z*-test and the 95% confidence interval (CI), both based on the Poisson model to compare the rate ratio (RR) between the preseason and the competitive season. RRs are presented with competitive season as the reference group. Two-tailed *P*-value ≤ 0.05 was regarded as significant. Categorical variables were compared with the χ^2 test. Linear regression analyses with normality assumptions were used to estimate the change in injury incidence over the study period. We used injury incidence as the dependent variable and year as the independent variable ($n = 6$). A general estimating equation (GEE) model approach was also used with teams as clustering factor and correlation structure chosen as exchangeable. A robust estimation method was undertaken. Linear regression and GEE were done by STATA 12 (StataCorp LP, TX, USA). We used chi-square statistics to compare the proportion of re-injuries over the study period.

Results

A total of 494 157 h of activity were registered during the 6-year long study period; 348 521 h (70.5%) of football training, 84 503 h (17.1%) of other training and 61 133 (12.4%) match hours. A total of 2365 injuries were recorded; 1664 (70.4%) acute injuries and 701 (29.6%) overuse injuries (Table 1).

Injury incidence

The overall injury incidence during the study period was 4.8 (95% CI: 4.6 to 5.0) per 1000 h of activity, 3.4 (95% CI: 3.2 to 3.5) acute injuries, and 1.4 (95% CI: 1.3 to 1.5) overuse injuries. Of the 1664 acute injuries, 969 (58.2%) occurred during match play, 655 (39.4%) during football training, and 40 (2.4%) during other training. The overall incidence of acute match injuries was 15.9 per 1000 h (95% CI: 14.9 to 16.8), whereas the incidence of acute injuries during football training and other training was 1.9 (95% CI: 1.7 to 2.0) and 0.5 (95% CI: 0.3 to 0.6), respectively. Using the aggregated injury incidence each season as dependent variable in a linear regression model ($n = 6$), the acute match injury incidence showed a yearly estimated increase of 1.06 injuries/1000 h (95% CI: 0.40 to 1.73, $P = 0.012$; Fig. 1). This corresponds to an estimated total increase of 49% over the 6-year observation period. When accounting for interteam variation and clustering effects using a GEE model, the increase in injury incidence was 0.92 (95% CI: −0.11 to 1.95, $P = 0.083$). Correspondingly, the aggregated league match injury incidence showed an annual increase of 0.66 injuries/1000 h (95% CI: 0.01 to 1.31, $P = 0.048$), which was not significant when correcting for interteam variation in the GEE model (0.69 injuries/1000 h, 95% CI: −0.68 to 2.06, $P = 0.32$). We did not detect any change in the incidence of overuse injuries ($P = 0.73$), nor in acute training injuries ($P = 0.49$) during the 6-year study period.

Injury severity

About half of acute training (51%), acute match (49%), and overuse injuries (55%) were mild (i.e., the player was able to return within a week). Severe injuries (> 21 days) constituted 21% of all injuries (Table 2). No significant change in the incidence of severe injuries was registered during the study period ($P = 0.44$). Knee joint injury (29%) was the most common type of severe acute injuries. Muscle injury to the groin (25%) was the predominant type of severe overuse injuries.

Table 1. Exposure and injuries over the six-season study period

Season	2002	2003	2004	2005	2006	2007
No. of teams	12	11	13*	14*	11	12
Exposure (h)	90 916	80 169	75 421	77 722	80 628	86 284
Football training	67 273	57 555	51 170	55 229	56 134	61 159
Other training	12 058	12 888	13 682	12 097	16 123	17 656
Match	11 586	9726	10 569	10 396	8371	10 486
Injuries (number)	424	422	368	373	332	446
Acute	271	299	248	282	254	310
Football training	115	139	86	106	90	119
Other training	6	10	6	10	6	2
Match	150	150	156	166	158	189
Overuse	153	123	120	91	78	136
Injury incidence						
Acute						
Football training	1.7	2.4	1.7	1.9	1.6	1.9
Other training	0.5	0.8	0.4	0.8	0.4	0.1
Match	12.9	15.4	14.8	16.0	18.9	18.0
Overuse	1.7	1.5	1.6	1.2	1.0	1.5
Acute match injury incidence						
Hip/groin	0.6	1.4	0.6	0.8	1.1	1.3
Thigh	3.2	3.4	2.9	3.2	5.0	4.3
Knee	1.4	2.7	2.9	2.3	3.2	2.6
Lower leg	1.1	1.9	2.3	1.4	1.8	1.9
Ankle	2.9	2.8	1.9	3.1	3.3	3.4

*Three clubs participated with match exposure and acute injuries.

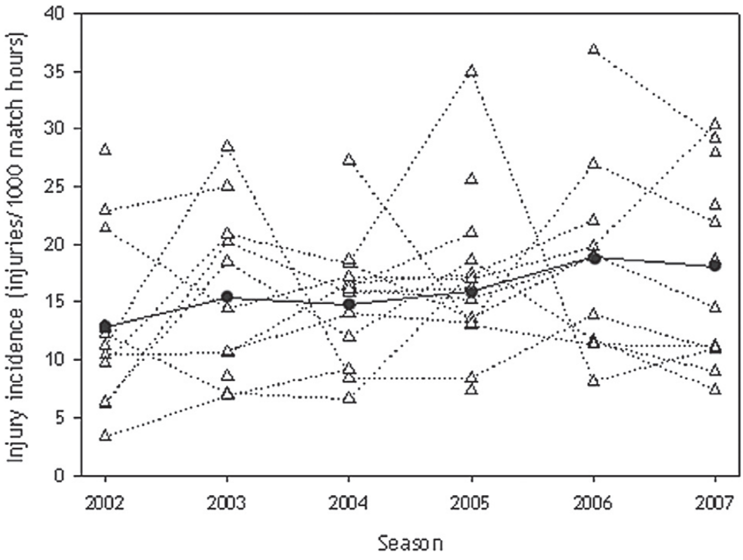

Fig. 1. The incidence of acute match injuries for all participating teams over the six-season study period ($n = 73$). The filled circles and solid line depicts the aggregated incidence of acute match injuries.

Injury type and localization

The most common injury type was muscle injuries (46%), followed by joint injuries (27%) and contusions (14%; Table 2). There was no significant change in muscle ($P = 0.92$) or joint injury incidence ($P = 0.95$) during the 6-year study period. We registered a total of 137 knee ligament injuries. Of these, there were 95 medial collateral ligament injuries, 16 lateral collateral ligament, 20 anterior cruciate ligament, and six posterior cruciate ligament injuries. The overall rate of anterior cruciate ligament injuries was 0.04 (95% CI: 0.02 to

Table 2. Injury pattern of injuries by severity

	Acute match injuries				Acute training injuries				Overuse injuries			
	Total (*N*)	1–7 days *N* (%)	8–21 days *N* (%)	>21 days *N* (%)	Total (*N*)	1–7 days *N* (%)	8–21 days *N* (%)	>21 days *N* (%)	Total (*N*)	1–7 days *N* (%)	8–21 days *N* (%)	>21 days *N* (%)
	969	471 (49)	293 (30)	205 (21)	655	334 (51)	181 (28)	140 (21)	701	386 (55)	176 (25)	139 (20)
Injury location												
Head/neck	96	57 (59)	23 (24)	16 (17)	18	11 (61)	4 (22)	3 (17)	9	9 (100)	0 (0)	0 (0)
Upper limbs	33	12 (36)	10 (30)	11 (33)	28	12 (43)	8 (29)	8 (29)	6	5 (83)	1 (17)	0 (0)
Trunk	62	28 (45)	22 (36)	12 (19)	47	26 (55)	14 (30)	7 (15)	75	42 (56)	19 (25)	14 (19)
Buttock	13	6 (46)	3 (23)	4 (31)	7	5 (71)	2 (29)	0 (0)	27	17 (63)	10 (37)	0 (0)
Hip/groin	58	27 (47)	19 (33)	12 (21)	44	22 (50)	11 (25)	11 (25)	153	84 (55)	35 (23)	34 (22)
Thigh	221	109 (49)	74 (34)	38 (17)	180	77 (43)	71 (39)	32 (18)	105	79 (75)	21 (20)	5 (5)
Knee	151	45 (30)	48 (32)	58 (38)	117	50 (43)	25 (21)	42 (36)	111	52 (47)	28 (25)	31 (28)
Lower leg	105	62 (59)	28 (27)	15 (14)	55	32 (58)	13 (24)	10 (18)	61	38 (62)	13 (21)	10 (16)
Ankle	177	101 (57)	55 (31)	21 (12)	124	80 (65)	30 (24)	14 (11)	111	43 (39)	40 (36)	28 (25)
Foot/toe	53	24 (45)	11 (21)	18 (34)	35	19 (54)	3 (9)	13 (37)	43	17 (40)	9 (21)	17 (40)
Injury type												
Fracture	63	9 (14)	12 (19)	42 (67)	33	4 (12)	10 (30)	19 (58)	24	0 (0)	3 (13)	21 (88)
Contusions	225	177 (79)	39 (17)	9 (4)	94	79 (84)	12 (13)	3 (3)	6	3 (50)	3 (50)	(0)
Laceration	25	20 (80)	4 (16)	1 (4)	5	5 (100)	0 (0)	0 (0)	–	–	–	–
Joint and ligament	317	134 (42)	105 (33)	78 (25)	248	124 (50)	58 (23)	66 (27)	66	33 (50)	8 (12)	25 (38)
Muscle and tendon	277	100 (36)	112 (40)	65 (24)	250	106 (42)	95 (38)	49 (20)	530	307 (58)	147 (28)	76 (14)
Nervous system	40	19 (48)	13 (33)	8 (20)	8	5 (63)	3 (38)	0 (0)	2	1 (50)	(0)	1 (50)
Pain	20	10 (50)	8 (40)	8 (10)	14	10 (71)	1 (7)	3 (21)	34	17 (50)	9 (27)	8 (24)
Other	2	2 (100)	0 (0)	0 (0)	3	1 (33)	2 (67)	0 (0)	39	25 (64)	6 (15)	8 (20)

0.06) per 1000 h, 0.25 (95% CI: 0.12 to 0.37) during matches, and 0.01 (95% CI: 0.00 to 0.03) during training. The thigh (22%) was the most common injury localization, followed by the ankle (18%), knee (16%), groin (11%), and lower leg (10%). The rate of hamstrings injuries was 1.54 (95% CI: 1.23 to 1.85) during matches and 0.25 (95% CI: 0.19 to 0.30) during training; correspondingly, the incidence of quadriceps injuries was 0.49 (95% CI: 0.32 to 0.67) during matches and 0.15 (95% CI: 0.11 to 0.19) during training. The rate of ankle sprains was 2.31 (95% CI: 1.93 to 2.69) during matches and 0.31 (95% CI: 0.25 to 0.37) during training. There were no significant changes in injury localization over the six-season study period; however, there was a trend toward an increased incidence of thigh injuries during matches ($P = 0.09$).

Reinjuries

Approximately 20% of all injuries were reinjuries. Muscle injuries were responsible for 58% of the reinjuries, most commonly localized to the thigh and hip/groin. The proportion of reinjuries was stable during the study period ($P = 0.83$).

The injury risk during the preseason vs the competitive season

The incidence of acute match injuries during the preseason was 14.0 per 1000 h (95% CI: 12.0 to 16.1) and 16.3 (95% CI: 15.2 to 17.5) during the competitive season. The acute training injury incidence during the preseason was 2.1 (95% CI: 1.8 to 2.3) compared to 1.8 (95% CI: 1.6 to 2.0) during the competitive season. The incidence of overuse injuries during the preseason was 1.5 (95% CI: 1.3 to 1.6) and 1.4 (95% CI: 1.3 to 1.5) during the competitive season. The RR for the preseason relative to the competitive season was 0.86 (95% CI 0.73 to 1.01) for acute match injuries, 1.16 (95% CI 0.99 to 1.36) for acute training injuries, and 1.04 (95% CI 0.89 to 1.21) for overuse injuries. Acute match injuries peaked during the first month of the competitive season, and toward the end of the competitive season. The risk of overuse injuries and acute training injuries was relatively constant during the season (Fig. 2).

We found a significantly higher risk of acute injuries with moderate severity and acute knee injuries during preseason training (Table 3). The risk of mild acute match injuries was higher during the competitive season.

Discussion

The aim of this study was to monitor injury incidence and pattern over six seasons in Norwegian male professional football. The main finding was that the overall risk of acute match injuries increased during the study period; however, using a conservative statistical model

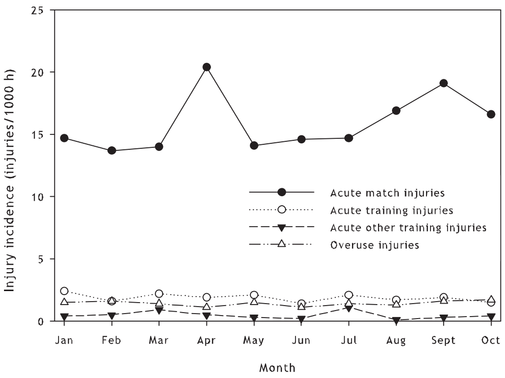

Fig. 2. The distribution of injuries over the football season.

correcting clustering effects showed that interteam variation was substantial. Our results are in contrast to a recent 7-year study from the top European professional level, where no change was seen (Ekstrand et al., 2010). Notably, we did not find any significant differences in the risk of acute training injuries or overuse injuries nor could we detect any changes in injury type, location, severity, or the proportion of reinjuries during the study period.

This study was a 6-year follow-up, giving us the possibility to follow the variations in injury risk and patterns over time. In addition, in this study, the number of injuries registered is high compared to most other studies on injury risk in professional football. Nevertheless, there is still a possibility of a type II error resulting from limited data, especially when comparing the incidences in injury subcategories (e.g., for a specific injury location, type, or severity). While we observed an alarming 49% increase in acute match injury risk during the study period, the results also show that this increase was not fully consistent across teams. This is of course partly because of chance, as the average number of injuries per team per season was no more than 13, assuming an equal distribution between teams. Correcting for variability between teams and clustering effects (that players within teams may be more alike than between teams), as we have done with the GEE model, may therefore represent an overly conservative approach.

The injury incidence of acute match and training injury is still lower in Norwegian male professional football compared to other professional leagues in Europe (Hawkins & Fuller, 1999; Hagglund et al., 2005, 2009; Walden et al., 2005b; Ekstrand et al., 2010). A recent methodological study showed that medical staff reporting failed to capture about 20% of all time loss injuries in Norwegian professional football (Bjorneboe et al., 2011). However, we would expect that there is underreporting in other studies as well, and even if we underestimated match injury incidence by 20%, it would still be lower than other studies (25.9 to 34.8 injuries/1000 match hour; Hawkins & Fuller, 1999; Hagglund et al., 2005; Walden et al., 2005b; Ekstrand et al., 2010).

Dupont et al. (2010) found, in a study of the effect of two matches per week vs one, that the recovery time was sufficient to maintain the level of physical performance, but the injury rate was significantly increased when playing two matches per week (Dupont et al., 2010). During the study period, the Norwegian league was a double round robin competition with home and away matches between 14 teams, played from April throughout October, resulting in each team playing a total of 26 league matches, or an average of 3.7 matches per month. In contrast, the English league runs over 9 months (August–May), and consists of 20 teams, giving an average of 4.2 matches per month. In addition, few Norwegian teams participated in European cups [Champions League and Union of European Football Associations (UEFA) cup]. As the Norwegian league ended late October, many of the European games were played ‘off-season’, thus not increasing the monthly match rate. Thus, players in the Norwegian league play a lower number of games than players at the Champions League level, and other European leagues. Moreover, the number of match hours per club was fairly stable over the study period. However, a limitation of the Norwegian injury surveillance system is that exposure data is only collected on a team basis, i.e., the total number of players present during each practice. We are therefore not able to test whether the total load (number of games) per player has increased during the study period nor are we able to examine potential risk factors for the onset of overuse injuries leading to absence from training or match for each player. It has been recommended that exposure is recorded on an individual basis (Fuller et al., 2006).

There have been no major changes in the Norwegian league system or rule interpretation nationally that could explain the possible increasing risk of acute match injuries. The first of four match venues with artificial turf was introduced during the second half of the 2005 season. However, a recent study on the risk of injury in Norwegian male professional football found no significant difference in injury rate between natural grass and artificial turf (Bjorneboe et al., 2010). This is in correspondence with other studies comparing the risk of injury on third-generation artificial turf to natural grass (Ekstrand et al., 2006; Fuller et al., 2007a, b; Steffen et al., 2007; Soligard et al., 2010). The proportion of match hours on artificial turf was 26% in the 2006 and 2007 seasons, and if the increased risk seen in match injuries were solely because of the introduction of artificial turf, the injury risk on artificial turf would have had to be about 33 injuries/1000 match hour. However, our data suggest that the match injury incidence was 17.6 (95% CI: 14.7–20.5) on artificial turf (Bjorneboe et al.,

Table 3. Characteristics of injuries sustained during the preseason and competitive season. The incidences are reported per 1000 h of exposure with 95% confidence intervals. Rate ratios between injuries on preseason and competitive season are shown with 95% confidence intervals, with the competitive season as the reference group

	Preseason		Competitive season		Preseason vs competitive season
	Injuries	Incidence	Injuries	Incidence	Rate ratio
Acute match injuries					
Injury type					
Fracture	13	1.0 (0.5–1.6)	50	1.0 (0.7–1.3)	0.97 (0.56–1.90)
Muscle and tendon	43	3.3 (2.3–4.3)	234	4.9 (4.2–5.5)	0.69 (0.50–0.95)
Joint and ligament	71	5.5 (4.2–6.8)	246	5.1 (4.5–5.7)	1.08 (0.83–1.40)
Contusions	38	2.9 (2.0–3.9)	187	3.9 (3.3–4.4)	0.76 (0.54–1.08)
Body location					
Groin	6	0.5 (0.1–0.8)	52	1.1 (0.8–1.4)	0.43 (0.19–1.00)
Thigh	45	3.6 (2.5–4.5)	176	3.6 (3.1–4.2)	0.96 (0.76–1.45)
Knee	29	2.2 (1.4–3.1)	122	2.5 (2.1–3.0)	0.88 (0.75–1.69)
Ankle	47	3.6 (2.6–4.7)	130	2.7 (2.2–3.2)	1.35 (0.97–1.88)
Time loss					
1–7 days	77	6.0 (4.6–7.3)	394	8.2 (7.4–9.0)	0.73 (0.57–0.93)*
8–21 days	65	5.0 (3.8–6.3)	228	4.7 (4.1–5.3)	1.07 (0.81–1.40)
> 21 days	39	3.4 (2.1–4.0)	166	3.4 (2.9–4.0)	0.88 (0.62–1.24)
Acute training injuries					
Injury type					
Fracture	10	0.1 (0.0–01)	23	0.1 (0.1–0.1)	0.89 (0.42–1.86)
Muscle and tendon	90	0.8 (0.6–0.9)	160	0.7 (0.6–0.8)	1.15 (0.89–1.48)
Joint and ligament	87	0.8 (0.6–0.9)	161	0.7 (0.6–0.8)	1.10 (0.85–1.43)
Contusions	37	0.3 (0.2–0.4)	57	0.2 (0.2–0.3)	1.32 (0.88–2.00)
Body location					
Groin	16	0.1 (0.1–0.2)	28	0.1 (0.1–0.2)	1.17 (0.63–2.15)
Thigh	63	0.5 (0.4–0.7)	117	0.5 (0.4–0.6)	1.10 (0.81–1.49)
Knee	49	0.4 (0.3–0.5)	68	0.3 (0.2–0.4)	1.47 (1.02–2.12)*
Ankle	40	0.3 (0.2–0.5)	84	0.4 (0.3–0.4)	0.97 (0.66–1.41)
Time loss					
1–7 days	102	0.9 (0.7–1.1)	232	1.0 (0.9–1.1)	0.89 (0.71–1.13)
8–21 days	80	0.7 (0.5–0.9)	101	0.4 (0.3–0.5)	1.61 (1.20–2.17)*
> 21 days	56	0.5 (0.4–0.6)	84	0.4 (0.3–0.4)	1.36 (0.97–1.91)
Overuse injuries					
Injury type					
Muscle and tendon	190	1.1 (1.0–1.3)	340	1.0 (0.9–1.2)	1.09 (0.91–1.30)
Joint and ligament	15	0.1 (0.0–0.1)	51	0.2 (0.1–0.2)	0.57 (0.32–1.02)
Body location					
Groin	59	0.4 (0.3–0.4)	94	0.3 (0.2–0.3)	1.22 (0.88–1.69)
Thigh	34	0.2 (0.1–0.3)	71	0.2 (0.2–0.3)	0.93 (0.62–1.40)
Knee	40	0.2 (0.2–0.3)	71	0.2 (0.2–0.3)	1.11 (0.74–1.61)
Ankle	37	0.2 (0.2–0.3)	74	0.2 (0.2–0.3)	0.97 (0.66–1.44)
Time loss					
1–7 days	127	0.8 (0.6–0.9)	259	0.8 (0.7–0.9)	0.95 (0.77–1.18)
8–21 days	71	0.4 (0.3–0.5)	105	0.3 (0.3–0.4)	1.32 (0.97–1.78)
> 21 days	46	0.3 (0.2–0.4)	93	0.3 (0.2–0.3)	0.96 (0.68–1.37)

*Significant difference in injury risk between the preseason and the competitive season.

2010), thus excluding artificial turf as the explanation for the increased risk of match injuries.

Another weakness of this study was the lack of information about injury mechanism on the injury card. Thus, we are not able to examine whether there have been any changes in the causes of injuries over the study period. Previous studies have shown that the majority of acute match injuries occur because of player-to-player contact (Hawkins & Fuller, 1999; Andersen et al., 2004a, b, c). However, only between 12% and 31% of all injuries are regarded as foul play by the referee (Luthje et al., 1996; Hawkins & Fuller, 1999; Andersen et al., 2004b; Arnason et al., 2004; Junge et al., 2004; Dvorak et al., 2011).

We found that about 30% of all injuries were overuse injuries and that the rate remained constant during the study period. Previous studies have shown that the proportion of overuse injuries ranges from 9% to 39% (Arnason et al., 1996; Walden et al., 2005b). However, a significant proportion of overuse injuries do not lead to time loss from sports participation; players often continue training and playing matches even when limited by pain and reduced function. Overuse injuries are therefore underestimated in most injury surveillance studies (Bahr, 2009). Therefore, we cannot exclude that the risk of overuse or acute injuries not leading to time loss from matches or training has increased, as our injury surveillance system does not detect these.

As our injury surveillance system was established prior to the consensus statement, the severity categories used differ slightly from the consensus statement. However, that about half of all injuries sustained by Norwegian professional players resulted in absence from football activity of 1 week or less is in accordance with other studies (Ekstrand & Gillquist, 1983; Hagglund et al., 2005; Ekstrand et al., 2010). Early studies of the injury risk among male elite players found that the knee was the most common injury location (Ekstrand & Gillquist, 1983; Engstrom et al., 1990). However, in modern football, there seems to be a shift toward an increased proportion of thigh injuries (Walden et al., 2007; Hagglund et al., 2009; Ekstrand et al., 2010). In our study, most injuries affected the lower extremities, with the thigh, knee, and ankle being the predominant injury localizations. Despite finding a lower incidence of match and training injuries, the injury pattern found in our study is in accordance with previous studies in comparable level of play and we could not detect any substantial changes during the study period.

Reinjuries constituted 20% of all injuries; this is in accordance with most other studies at the top national level (Walden et al., 2005a; Hagglund et al., 2006). However, a recent study of teams competing in the UEFA Champions League had a reinjury rate of only 12%. This was explained by a bigger medical team, providing more personalized rehabilitation after injuries (Ekstrand et al., 2010). In addition, the squad size at the top level is probably bigger than in Norwegian teams. It gives the teams the opportunity to utilize the squad depth, and rest players, to allow for full recovery from previous injuries. Nevertheless, there is a need for increased focus on risk management with tailored individual physical training programs and load monitoring.

We could not detect any significant differences in risk of injuries between the preseason and the competitive season. However, there was a tendency toward an increased risk of acute match injuries and lower risk of acute training injuries during the competitive season. Previous studies (Hawkins & Fuller, 1999; Ekstrand et al., 2010) have showed an increased risk of overuse injuries during the preseason and a lower risk of traumatic training injuries during the preseason. In contrast, a Swedish study found an increased risk of training injuries during the preseason (Walden et al., 2005a). However, there is a difference in the league system in Norway and Sweden compared to most European leagues. Because of climatic conditions, the Norwegian and Swedish league goes from April to October/November, with a 3-month preseason period starting in January. Most other European leagues have a 4- to 6-week preparation period. Thus, the preseason in other European leagues may be more intense and strenuous, with a correspondingly higher risk of injury. In addition, the coaching, fitness and medical staff in Norway have a longer period to get the players match fit, with the possibility for an increased focus on individual adjustments.

In conclusion, the overall risk of acute match injury in Norwegian male professional football increased by 49% during the six-season study period, although this increase was not fully consistent across teams. We detected no change in the risk of training or overuse injuries or any difference between the preseason and competitive season.

Perspectives

Injury surveillance is a key risk management tool to monitor injury incidence and injury patterns to ensure the safety of the players. The next step in the four-step sequence of injury prevention is to analyze injury risk factors and injury mechanisms (van Mechelen et al., 1992). Andersen and coworkers (2004b) found through video analysis that less than one-third of injuries identified on video, and 40% of high-risk situations resulted in a free kick being awarded. It has been shown through video analysis of tackling parameters in FIFA tournaments that tackles from the side were twice as likely to require post-match medical attention (Fuller et al., 2004). However, video analysis of high-risk injury situations and recorded injuries should be conducted to establish whether the increased risk of match injuries observed is the result of lax rule enforcement or more foul play.

Key words: soccer, injuries, Norway, epidemiology, male.

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III

Risk of injury on third-generation artificial turf in Norwegian professional football

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Accepted 1 June 2010

ABSTRACT

Background Artificial turf is used extensively in both recreational and elite football in areas with difficult climatic conditions.
Objective To compare the risk for acute injuries between natural grass (NG) and third-generation artificial turf (3GAT) in male professional football.
Study design Prospective cohort study.
Methods All injuries sustained by players with a first-team contract were recorded by the medical staff of each club, from the 2004 throughout the 2007 season. An injury was registered if the player was unable to take fully part in football activity or match play.
Results A total of 668 match injuries, 526 on grass and 142 on artificial turf, were recorded. The overall acute match injury incidence was 17.1 (95% CI 15.8 to 18.4) per 1000 match hours; 17.0 (95% CI 15.6 to 18.5) on grass and 17.6 (95% CI 14.7 to 20.5) on artificial turf. Correspondingly, the incidence for training injuries was 1.8 (95% CI 1.6 to 2.0); 1.8 (95% CI 1.5 to 2.0) on grass and 1.9 (95% CI 1.5 to 2.2) on artificial turf respectively. No significant difference was observed in injury location, type or severity between turf types.
Conclusion No significant differences were detected in injury rate or pattern between 3GAT and NG in Norwegian male professional football.

INTRODUCTION

Many regions of the world suffer from climatic conditions that limit natural grass (NG) growth throughout the seasons. It is therefore difficult to maintain adequate NG pitches in cold and wet climate zones in the northern hemisphere and in dry areas around the equator. Artificial turf provides for more constant playing conditions, longer playing hours and lower maintenance costs compared with NG.[1] Consequently, some national football associations, including the Norwegian, recommend artificial turf for new football pitches.

While there are some studies on the injury risks associated with artificial turf in European football, showing a higher risk of injury compared with NG,[2 3] most have been carried out on first- and second-generation artificial turf. However, early turf types displayed characteristics clearly different from those of NG, including differences in bounce and roll of the ball. This led to the development of a third-generation of artificial turf types (3GAT), with long grass-like fibres filled with sand and rubber particles, named football turf by Federation Internationale de Football Association (FIFA) and included in the Laws of the game in 2004.[1]

In 2006, Ekstrand and coworkers published the first study looking at injury risk on artificial turf in male elite football. They found no major differences in injury risk between artificial turf and NG except, surprisingly, a higher incidence of ankle sprains on artificial turf.[4] Studies in college and youth football have revealed a similar risk of injury on NG compared with artificial turf,[5-8] while Steffen and coworkers found a higher risk of severe match injuries on artificial turf.[7] However, in these studies, exposure was on a mixture of turf types, including first- and second-generation turf.

The aim of this study was to compare the risk of acute injuries on NG to 3GAT in male professional football, where all teams have access to 3GAT.

MATERIALS AND METHODS

Study design and population

The study population included players with a first-team contract with one of the 14 clubs in the male Norwegian professional league (Tippeligaen). As part of a continuous prospective injury surveillance system established in 2000,[9] all injuries sustained were recorded by the medical staff of each club. The present study includes data from 2004 throughout the 2007 season (January to December). Players on trial or youth players without a professional contract were not included. All artificial turfs were FIFA-certified. NG used in football in Norway is commonly a mix of rye grass and poa pratensis.

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

Injury definition and injury form

We used a time-loss definition, in accordance with a recent consensus statement,[10] when recording injuries. An injury was registered if the player was unable to take part fully in football activity or match play at least 1 day beyond the day of injury. If the injury was the result of a specific, identifiable event, it was defined as acute and included in this paper. Overuse injuries were not included, as they could not be attributed to a specific training session or match (and, hence, turf type). We designed the injury form according to the consensus statement, including information about the date of injury, the type of activity (match or training) in which the injury occurred, injury location and injury history. We categorised injuries into three severity categories according to the duration of absence from match and training sessions: mild (1–7 days), moderate (8–21 days) and severe

Br J Sports Med 2010;**44**:794–798. doi:10.1136/bjsm.2010.073783

(>21 days). We classified the injury diagnoses using Orchard codes.[11]

Injury registration by medical staff

A member of the club medical staff, in most cases the physiotherapist, sometimes the team physician, performed the prospective injury registration. Each season, we sent a manual, with instructions on how to complete the injury and exposure forms to the club medical staff. The club licence for Norwegian professional football clubs requires that a chartered physiotherapist be available for the club, and they usually attend all organised team activities, that is, all training sessions and matches. We collected the forms on a monthly basis, and if needed, we followed up with reminder text messages and phone calls. We controlled the injury cards submitted thoroughly. If information was missing or we discovered any other inconsistencies, a member of the study group contacted the medical staff for clarification.

Exposure registration

We collected exposure data on a separate form, asking for information about the type and duration of match or training, the number of participants and the surface during the particular training or match. Match exposure for players included all matches between teams from different clubs of players with an A-squad contract. Training exposure was defined as any physical activity carried out under the guidance of a member of the first teams coaching staff. A member of the coaching staff or the medical staff completed the exposure form.

Statistics

Results are presented as injury incidence (injuries/1000 h of exposure) in training and match play. We used a z test and the 95% CI based on the Poisson model to compare the rate ratio between artificial turf and NG. To adjust for the correlation between the dichotomy match/training and both injury and artificial turf/NG, overall injury incidence on NG/artificial turf was calculated using a stratified analysis by match/training. The pooled estimate NG/artificial turf across the strata (match/training) was made by a weighted average using the reciprocal of the variances of the rates as weights. Rate ratios are presented with NG as the reference group. Two-tailed p values ≤0.05 were regarded as significant. All analyses were conducted in SPSS for Windows V.15 (SPSS, Chicago, Illinois).

RESULTS

A total of 261 541 playing hours, 186 929 (71.5%) on grass and 74 612 (28.5%) on artificial turf, were registered during the 4-year long study period. A total of 1067 injuries were recorded, of which 800 (75%) were on grass, and 267 (25%) were on artificial turf, corresponding to an overall injury incidence of 2.1 (95% CI 1.9 to 2.3) per 1000 playing hours on NG and 2.1 (95% CI 1.8 to 2.4). There was no significant difference in overall risk of injury between grass and artificial turf (rate ratio 1.01, 95% CI 0.87 to 1.15).

The total match exposure was 38 976 playing hours, 30 927 (79%) on grass and 8049 (21%) on artificial turf. A total of 668 match injuries, 526 (79%) on grass and 142 (21%) on artificial turf, was recorded, corresponding to an overall injury incidence during matches of 17.1 (95% CI 15.8 to 18.4) per 1000 match hours, 17.0 (95% CI 15.6 to 18.5) on grass and 17.6 (95% CI 14.7 to 20.5) on artificial turf. There was no significant difference between grass and artificial turf during matches (rate ratio 1.04, 95% CI 0.86 to 1.25).

The total training exposure was 222 565, 156 002 (70%) and 66 563 (30%) on grass and artificial turf, respectively, while there were 399 training injuries, 274 (69%) on grass and 125 (31%) on artificial turf. Correspondingly, the incidence of training injuries was 1.8 (95% CI 1.6 to 2.0), 1.8 (95% CI 1.5 to 2.0) on grass and 1.9 (95% CI 1.5 to 2.2) on artificial turf. There was no significant difference between grass and artificial turf during training (rate ratio 1.07, 95% CI 0.87 to 1.32).

No significant differences were observed in injury incidence between grass and artificial turf for match (table 1) or training injuries (table 2) in any of the subcategories injury location, severity or injury type (tables 1, 2).

DISCUSSION

The aim of this study was to compare the risk for acute injuries between NG and 3GAT in male professional football. We could not detect any significant differences between turf types for training or match injuries, or in any injury subcategory. This is in accordance with previous studies comparing the risk of injury on 3GAT to NG.[4-8]

A limitation of this study is that we were not able to compare the risk of overuse injuries on artificial turf to that on NG. There are two main obstacles to making such a comparison. One limitation is that a significant proportion of overuse injuries do not lead to time loss from sports participation; players often continue training and playing games even when limited by pain and reduced function. Studies based on surveillance data, such as the present, are usually based on an injury definition requiring time loss from football, and therefore lead to a significant underestimation of overuse injuries in the population.[12] Second, overuse injuries are defined as being the result of repeated micro-trauma without a single, identifiable event responsible for the injury.[10] Therefore, even if a ‘physical complaint’ definition were used, an overuse injury cannot be attributed to one specific training session or match and, hence, to one of the two turf types in question. To date, there is no obvious solution to these challenges. If appropriate methods are developed to quantify overuse injuries in athletes,[12] it may be possible to compare teams who play and train on one turf type entirely, although it would be difficult to control for confounding factors in such a study. Also, there may be an association between increased risk of overuse injuries and lack of adaptation or frequent changes in playing surface.[2 13-15]

One strength of this study was the 4-year follow-up, and the high number of acute time-loss injuries registered compared with other studies on the same topic. This means that the 95% CI for the rate ratio between grass and artificial turf was quite narrow; ranging from 0.87 to 1.15. Nevertheless, there is still a possibility of a type II error resulting from limited data, especially when comparing the incidences in subcategories of injuries (eg, for a specific injury location, type or severity). We did observe a trend towards an increased risk of knee and ankle sprains on artificial turf, albeit only during matches. Ekstrand *et al*[4] found a significant difference and Steffen *et al*[7] a trend towards an increased risk of ankle sprains on artificial turf. Ekstrand *et al*[4] also saw a trend towards a reduced risk of muscle injuries on artificial turf; there was no indication of this in our study. Eleven anterior

Table 1 Characteristics of acute match injuries

	Grass		Artificial turf		Artificial turf versus grass
	Injuries	Incidence	Injuries	Incidence	Rate ratio
Injury type					
Fracture	34	1.1 (0.7 to 1.5)	7	0.9 (0.2 to 1.5)	0.79 (0.35 to 1.78)
Sprain	165	5.3 (4.5 to 6.1)	57	7.1 (5.2 to 8.9)	1.33 (0.98 to 1.79)
Knee	63	2.0 (1.5 to 2.5)	24	3.0 (1.8 to 4.2)	1.46 (0.92 to 2.34)
Ankle	69	2.2 (1.7 to 2.8)	25	3.1 (1.9 to 4.3)	1.39 (0.88 to 2.20)
Strain	157	5.1 (4.3 to 5.9)	36	4.5 (3.0 to 5.9)	0.88 (0.61 to 1.27)
Groin	38	1.2 (0.8 to 1.6)	6	0.7 (0.1 to 1.3)	0.61 (0.26 to 1.44)
Hamstring	55	1.8 (1.3 to 2.2)	13	1.6 (0.7 to 2.5)	0.91 (0.50 to 1.66)
Quadriceps	18	0.6 (0.3 to 0.9)	5	0.6 (0.1 to 1.2)	1.07 (0.37 to 2.88)
Calf	28	0.9 (0.6 to 1.2)	7	0.9 (0.2 to 1.5)	0.96 (0.42 to 2.20)
Contusion	119	3.8 (3.2 to 4.5)	32	4.0 (2.6 to 5.4)	1.03 (0.70 to 1.53)
Cut	12	0.4 (0.2 to 0.6)	6	0.7 (0.1 to 1.3)	1.92 (0.72 to 5.12)
Nervous system	26	0.8 (0.5 to 1.2)	3	0.4 (0.0 to 0.8)	0.44 (0.13 to 1.47)
Other	13	0.4 (0.2 to 0.6)	1	0.1 (−0.1 to 0.4)	0.30 (0.04 to 2.26)
Body location					
Head/neck	61	2.0 (1.5 to 2.5)	9	1.1 (0.4 to 1.8)	0.57 (0.28 to 1.14)
Concussion	42	1.4 (0.9 to 1.8)	5	0.6 (0.1 to 1.2)	0.46 (0.18 to 1.16)
Upper extremity	18	0.6 (0.3 to 0.9)	3	0.4 (0.0 to 0.8)	0.64 (0.19 to 2.17)
Trunk	34	1.1 (0.7 to 1.5)	12	1.5 (0.6 to 2.3)	1.36 (0.70 to 2.62)
Lower extremity					
Groin	48	1.6 (1.1 to 2.0)	11	1.4 (0.6 to 2.2)	0.88 (0.46 to 1.70)
Thigh	107	3.5 (2.8 to 4.1)	31	3.9 (2.5 to 5.2)	1.11 (0.75 to 1.66)
Knee	83	2.7 (2.1 to 3.3)	26	3.2 (2.0 to 4.5)	1.20 (0.78 to 1.87)
Calf	64	2.1 (1.6 to 2.6)	10	1.2 (0.5 to 2.0)	0.60 (0.31 to 1.17)
Ankle	86	2.8 (2.2 to 3.4)	30	3.7 (2.4 to 5.1)	1.34 (0.89 to 2.03)
Foot	25	0.8 (0.5 to 1.1)	10	1.2 (0.5 to 2.0)	1.54 (0.74 to 3.20)
Time loss (days)					
1–7	263	8.5 (7.5 to 9.5)	64	8.0 (6.0 to 9.9)	0.94 (0.71 to 1.23)
8–21	151	4.9 (4.1 to 5.7)	39	4.8 (3.3 to 6.4)	0.99 (0.70 to 1.41)
>21	112	3.6 (3.0 to 4.3)	39	4.8 (3.3 to 6.4)	1.34 (0.93 to 1.93)

The incidences are reported per 1000 h of exposure (with 95% CI). Rate ratios between injuries on grass and artificial turf are shown with 95% CI, with grass as the reference group (n=668).

cruciate ligament (ACL) injuries occurred during match (nine on NG and two on artificial turf), three during training (two on NG and one on 3GAT). Our injury surveillance system was started in 2000, prior to the consensus statement.[10] Therefore, the severity categories we have used differ from the consensus statement. We observed a trend towards increased representation of training injuries with moderate severity (8–21 days) when playing on artificial turf. Studies from elite and youth football found a tendency towards an increased risk of severe injuries on artificial turf.[4 7] In contrast, Fuller *et al*[5 6] found no significant difference in severity, nature or cause of injuries between NG and artificial turf. At the other end of the severity spectrum are abrasions and friction injuries, which have been reported to be more common on first-generation artificial turf[14] but were unlikely to be captured using our time-loss injury definition. However, Soligard *et al*,[8] having recorded all physical complaints in an adolescent football tournament, found no significant difference in the risk of abrasions between artificial turf and NG. In summary, although the data from the current study indicate that there is no clinically meaningful difference in the overall risk for acute injuries, even larger studies or meta-analyses are needed to reach firm conclusions regarding specific injury types, such as knee sprains or ACL tears.

A recent methodological study showed that the medical staff fail to report/capture about 20% of all time-loss injuries in Norwegian professional football.[16] However, no significant difference was found related to surface when the injury was sustained, injury type, severity or body part.[16] Thus, the overall injury incidence in this study is probably underestimated, but this should not interfere with our comparison between artificial turf and NG.

It should be noted that first- and second-generation artificial turf had different playing characteristics from NG, which may explain the increased injury risk observed in older studies. Shoe–surface friction and surface stiffness are the two main factors involved in surface-related injuries.[17] 3GAT used in elite football are thoroughly tested before they are certified by FIFA as football turfs, that is, approved for use in professional football. FIFA's football turf certification regulates that shoe–surface friction and surface stiffness be within a specified range.[1] The current study is the first to include only 3GAT certified by FIFA. Because of the climate in Norway, football is mainly played from April to the end of October. The competitive season in the professional league starts in mid-March and ends early in November, with a preseason period from January. Surface traction is less in rainy weather and may also depend on temperature, but we have not collected weather information for the games played. However, most of the stadiums with artificial turf are watered before the game and during the halftime break in order to lower the traction forces.

Table 2 Characteristics of acute training injuries

	Grass		Artificial turf		Artificial turf versus grass
	Injuries	Incidence	Injuries	Incidence	Rate ratio
Injury type					
Fracture	13	0.1 (0.0 to 0.1)	5	0.1 (0.0 to 0.1)	0.90 (0.32 to 2.53)
Sprain	114	0.7 (0.6 to 0.9)	43	0.6 (0.5 to 0.8)	0.88 (0.62 to 1.26)
Knee	38	0.2 (0.2 to 0.3)	22	0.3 (0.2 to 0.5)	1.36 (0.80 to 2.29)
Ankle	48	0.3 (0.2 to 0.4)	17	0.3 (0.1 to 0.4)	0.83 (0.48 to 1.44)
Strain	101	0.6 (0.5 to 0.8)	52	0.8 (0.6 to 1.0)	1.21 (0.86 to 1.69)
Groin	15	0.1 (0.0 to 0.1)	10	0.2 (0.1 to 0.2)	1.56 (0.70 to 3.48)
Hamstring	37	0.2 (0.2 to 0.3)	16	0.2 (0.1 to 0.4)	1.01 (0.56 to 1.82)
Quadriceps	23	0.1 (0.1 to 0.2)	14	0.2 (0.1 to 0.3)	1.43 (0.73 to 2.77)
Calf	10	0.1 (0.0 to 0.1)	6	0.1 (0.0 to 0.2)	1.41 (0.51 to 3.87)
Contusion	34	0.2 (0.1 to 0.3)	21	0.3 (0.2 to 0.5)	1.45 (0.84 to 2.49)
Cut	1	–	0	–	–
Nervous system	4	–	2	–	–
Other	7	–	2	–	–
Body location					
Head/neck	8	–	1	–	–
Concussion	6	–	1	–	–
Upper extremity	16	0.1 (0.1 to 0.2)	5	0.1 (0.0 to 0.1)	0.73 (0.27 to 2.00)
Trunk	19	0.1 (0.1 to 0.2)	10	0.2 (0.1 to 0.2)	1.23 (0.57 to 2.65)
Lower body					
Groin	21	0.1 (0.1 to 0.2)	10	0.2 (0.1 to 0.2)	1.12 (0.53 to 2.37)
Thigh	74	0.5 (0.4 to 0.6)	35	0.6 (0.4 to 0.7)	1.11 (0.74 to 1.66)
Knee	52	0.3 (0.2 to 0.4)	27	0.4 (0.3 to 0.6)	1.22 (0.76 to 1.94)
Calf	22	0.1 (0.1 to 0.2)	10	0.2 (0.1 to 0.2)	1.07 (0.50 to 2.25)
Ankle	52	0.3 (0.2 to 0.4)	21	0.3 (0.2 to 0.5)	0.95 (0.57 to 1.57)
Foot	10	0.1 (0.0 to 0.1)	6	0.1 (0.0 to 0.2)	1.41 (0.51 to 3.87)
Time loss (days)					
1–7	152	1.0 (0.8 to 1.1)	50	0.8 (0.5 to 1.0)	0.77 (0.56 to 1.06)
8–21	74	0.5 (0.4 to 0.6)	45	0.7 (0.5 to 0.9)	1.43 (0.98 to 2.06)
>21	48	0.3 (0.2 to 0.4)	30	0.5 (0.3 to 0.6)	1.47 (0.93 to 2.31)

Incidences are reported per 1000 h of exposure with 95% CI. Rate ratios between injuries on grass and artificial turf are shown with 95% CI, with grass as the reference group (n=399).

Andersson *et al*[18] compared the movement patterns and ball skills on 3GAT with that on NG, and found no significant difference in running activities and technical standards. However, they also found that fewer sliding tackles and more short passes were performed when playing on artificial turf, which partly may explain the negative attitude of male players towards playing on artificial turf.[18]

High rotational traction is considered to be a risk factor for injuries to the lower extremities, and artificial turf has a significantly higher peak torque and rotational stiffness than NG in American football.[19] However, a shoe with a turf-style cleat produces a significantly lower torque than other shoes.[19] Generally, grass-style shoes have longer and fewer cleats, while turf-style shoes have shorter and rounder cleats. However, we are unable to control for the type of shoe used when injured in our analysis.

In conclusion, no significant differences were detected in injury rate or pattern between 3GAT and NG in Norwegian male professional football.

What is already known

- Artificial turf provides for more constant playing conditions, longer playing hours and lower maintenance costs.
- First- and second-generation artificial turf was associated with a higher injury risk.
- Recent studies have found no major difference in injury risk on third-generation artificial turf (3GAT) compared with natural grass (NG).

What this study adds

No significant differences were detected in acute injury rate or pattern between 3GAT and NG in male professional football.

Acknowledgements The authors would like to thank the players and the medical staff in Tippeligaen for their participation.

Funding The Oslo Sports Trauma Research Center has been established at the Norwegian School of Sport Sciences through generous grants from the Royal Norwegian Ministry of Culture and Church Affairs, the South-Eastern Norway Regional Health Authority, the Norwegian Olympic Committee & Confederation of Sport and Norsk Tipping AS.

Competing interests None.

Ethics approval Ethics approval was provided by the Regional Committee for Medical Research Ethics, Region Øst-Norge (region: eastern Norway).

Provenance and peer review Not commissioned; externally peer reviewed.

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IV

BJSM Online First, published on January 11, 2013 as 10.1136/bjsports-2012-091856

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

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Received 4 October 2012
Revised 29 November 2012
Accepted 5 December 2012

ABSTRACT

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

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

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

Results A total of 1287 incidents were identified during the two seasons. The corresponding rate of incidents was 74.4 (95% CI 67.3 to 81.5) in the 2000 season and 109.6 (95% CI 102.3 to 116.9) in the 2010 season, a significant increase from 2000 to 2010 (rate ratio 1.47, 95% CI 1.31 to 1.66). We observed a significantly higher rate of opponent-to-player contact and non-contact incidents in the 2010 season, but no change in the proportion of fouls or sanctions awarded by the referee. The rate of player-to-player contact situations in both heading and tackling duels was lower during the 2010 season.

Conclusions We found an increased rate of non-contact and opponent-to-player contact incidents in both heading and tackling duels in the 2010 season compared with 10 years earlier, even if there was no increase in the frequency of player-to-player contact situations.

INTRODUCTION

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

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

To cite: Bjørneboe J, Bahr R, Einar Andersen T. *Br J Sports Med* Published Online First: [*please include* Day Month Year] doi:10.1136/bjsports-2012-091856

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

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

MATERIALS AND METHODS

Video analysis

We collected videotapes of league matches prospectively throughout the 2000 and 2010 seasons for review by the study group. In 2000, the league was a double round robin competition with home and away matches between 14 teams, resulting in a total of 182 matches. Of these, 174 (96%) were available on video. Of the 174 videotapes, 157 covered the full match, while the remaining 17 covered 73 min on average (range: 36–87 min). The total duration of the video recordings was 15 367 min; thus, we were able to analyse 256 h (94%) of a total of 273 h of football matches in the 2000 season. The 256 h of match play corresponded to a total of 5632 player-match hours in the 2000 season. In 2010, 16 teams participated in the Norwegian male professional league. All of the 240 matches were available on video, corresponding to 360 h of match play and 7920 player-match hours in the 2010 season.

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

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

We also conducted a video analysis of all player-to-player contact situations between players from opposing teams in 30 matches (14 from the 2000 season and 16 from the 2010 season), irrespective of the consequences of the contact. A player-to-player contact situation was said to occur when there was body contact between two players from opposing teams. We included situations where the players were challenging for ball possession. We registered the type of duel (tackling, heading and other). For heading duels we included the contact between the two opponent players (trunk–trunk, head–head, arm–head and leg–head). To select games for analysis in the two seasons, a random draw was made using to bowls with a ball for each team, continuing the draw until we had picked one home match and one away match for each team participating in the league.

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

Statistics

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

RESULTS

Video analysis

A total of 1287 incidents were identified during the two seasons, 419 in 2000 and 868 in 2010. The corresponding overall rate of incidents was 74.4 per 1000 player-match hours of exposure (95% CI 67.3 to 81.5) in the 2000 season and 109.6 (95% CI 102.3 to 116.9) in the 2010 season, an increase from 2000 to 2010 (RR 1.47, 95% CI 1.31 to 1.66). We observed a higher rate of opponent-to-player contact incidents and non-contact incidents in the 2010 season. No difference was observed in the rate of incidents caused by teammate-to-player contact or ball-to-player contact (table 1).

Tackling and heading characteristics

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

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

Referee decision

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

Non-contact incidents

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

Table 1 Characteristics of incidents (n=1287) from video analysis of all games (n=414)

	2000		2010		2000 vs 2010
	Incidents	Rate	Incidents	Rate	Rate ratio
Contact opponent	353	62.7 (56.1 to 69.2)	734	92.7 (86.0 to 99.4)	1.48 (1.30 to 1.68)
Contact teammate	18	3.2 (1.7 to 4.7)	28	3.5 (2.2 to 4.8)	1.11 (0.61 to 2.00)
Non-contact	29	5.1 (3.3 to 7.0)	68	8.6 (6.5 to 10.6)	1.67 (1.08 to 2.58)
Contact ball	17	3.0 (1.6 to 4.5)	32	4.0 (2.6 to 5.4)	1.34 (0.74 to 2.41)
Other	2	0.4 (−0.1 to 0–8)	6	0.8 (0.2 to 1.4)	2.13 (0.43 to 10)

Rate is reported as the number of incidents per 1000 player-match hours with 95% CI. Rate ratios between the 2000 and 2010 seasons are shown with 95% CI, with the 2000 season as the reference group.

Table 2 Characteristics of incidents due to opponent-to-player contact (n=1087) from a video analysis of all games (n=414)

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

Rate is reported as the number of incidents per 1000 player-match hours with 95% CI. Rate ratios between incidents in the 2000 and 2010 seasons are shown with 95% CI, with the 2000 season as the reference group.

Player-to-player contact situations

During the 30 matches (14 in 2000 and 16 in 2010) a total of 3526 situations with player-to-player contact were identified, 1787 in 2000 and 1739 in the 2010 season. The corresponding overall rate of contact situations was 3868 (95% CI 3689 to 4047) in the 2000 season and 3294 (95% CI 3139 to 3448) in the 2010 season, a reduction from 2000 to 2010 (RR 0.85, 95% CI 0.80 to 0.91). We found a lower rate of player-to-player contact in both heading and tackling duels during the 2010 season (table 6).

DISCUSSION

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

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

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

Table 3 Characteristics of head injury incidents due to opponent-to-player contact from video analysis of all games (n=414)

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

Rate is reported as the number of incidents per 1000 player-match hours with 95% CI. Rate ratios between incidents in the 2000 and 2010 seasons are shown with 95% CI, with the 2000 season as the reference group.

Table 4 Tackling characteristics. Rate is reported per 1000 h of exposure with 95% CI from the video analysis of all games (n=414)

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

Rate is reported as the number of incidents per 1000 player-match hours with 95% CI, with the 2000 season as the reference group (n=530).

for the Norwegian Elite Football Injury Surveillance System[17] was adapted to the UEFA Injury Study Protocol.[6] However, it should be noted that we observed a gradual increase in the risk of acute match injuries in the league from 2002 to 2007,[14] suggesting that changes have occurred in the style of play. This seems to be the case, as we observed an increased frequency of duels (heading and tackling duels) leading to stoppage of play. Tackles from all directions, foot tackles and sliding tackles all increased, and there was a higher rate of tackles without ball contact and late tackles. The data also revealed an increased rate of contact incidents affecting the head/neck, trunk, thigh and calf/ankle. Previous studies on injury mechanisms in football have found that most ankle and head injuries are caused by player-to-player contact.[11 13 18] For ankle injuries, the most common cause of contact injury is being tackled to the weigh bearing limb, involving lateral and medial forces and the tackler staying on his feet.[11–13] The most common causes of head injuries and incidents are typically heading duels, arm-to-head contact, followed by head-to-head contact.[18] It is therefore a concern that we found an increased rate of duel incidents, and that the increased frequency of head incidents was a result of increased arm-to-head contact.

Table 5 Referee decision for different incidents caused by opponent-to-player contact from the video analysis of all games (n=414)

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

Proportions were compared using a χ^2 test.

We found no differences in the proportion of free kicks or sanctions for foul play awarded between the two seasons. We had no referee panel for the referees' decisions during matches; thus, we were not able to assess whether the decision called by the referee was correct according to the Laws of the Game. After the 2000 season, the referees' decisions were reviewed retrospectively by a Norwegian FIFA referee panel, concluding that the judgements of the match referee were according to the existing interpretation of the Laws of the Game. It was noted, however, that there might be a need for stricter rule interpretation or changes to the laws in order to protect players from dangerous play.[17]

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

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

The increasing rate of injuries found in Norwegian male professional football, and the increasing incidence of incidents

Table 6 Characteristics of player-to-player contact situations (n=3526) from the video analysis of 32 randomly picked matches

	2000		2010		2000 vs 2010
	Situations	Rate	Situations	Rate	Rate ratio
Duel type (n=3526)					
Heading duel	879	1903 (1777 to 2028)	816	1545 (1439 to 1652)	0.81 (0.74 to 0.89)
Tackling duel	637	1379 (1272 to 1486)	462	1233 (1138 to 1328)	0.89 (0.80 to 1.00)
Other duel	271	587 (517 to 656)	272	515 (454 to 576)	0.87 (0.74 to 1.04)

Situations rate is reported per 1000 player-match hours with 95% CI. Rate ratios between the 2000 and 2010 seasons are shown with 95% CI, with the 2000 season as the reference group.

found in the present study is alarming. An analysis of 11 859 papers on sports injury prevention across all sports showed that only 0.6% of the articles retrieved focused on rules and regulations, despite the fact that some of these studies showed significant effects on injury risk.[20] In addition, video analyses have shown that referees identify only 40% of head/neck injuries as foul play during FIFA tournaments.[21] It has therefore been suggested that knowledge regarding the injury potential of arm-to-head incidents is lacking among referees. As a consequence, the International Football Association Board gave referees the authority to sanction potentially injurious fouls, such as intentional elbows to the head, with a yellow or an automatic red card.[22] After this, the incidence of match injuries was significantly lower in the 2010 FIFA World Cup for men compared with the mean incidence found in the three previous World Cups.[23] This was partly explained by stricter rule enforcement. However, the effect of rule changes and a stricter interpretation and enforcement of the Laws of the Game have neither been evaluated through prospective injury surveillance systems nor using systematic video analyses. Our findings indicate that the increased incidence of head incidents can be explained by arm-to-head contact, which should be a concern for all stakeholders in football. We therefore encourage an evaluation of the existing Laws of the Game and their enforcement in order to reduce the risk of injury. A comparison of the incident and injury incidence before and after the introduction of stricter rule enforcement should be addressed in future studies.

In conclusion, we found an increased rate of non-contact and opponent-to-player contact incidents in both heading and tackling duels in the 2010 season compared with 10 years earlier, even if there was no increase in the frequency of duels.

What this study adds to existing knowledge

- We found an increased rate of incidents with a high injury potential in the 2010 season compared with the 2000 season. Little is known regarding the effect of changes in rules and regulations on the risk of injury in male professional football.

How might it impact on clinical practice in the near future

- The increased rate of incidents warrants further investigation. We encourage an evaluation of the existing Laws of the Game and their enforcement in order to reduce the risk of injury.

Acknowledgements We would like to thank Svein Inge Børven and Kenneth Wilsgård for analysing 30 matches for all player-to-player contact.

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

Funding This study was supported by grants from the FIFA Medical Assessment and Research Centre. The Oslo Sports Trauma Research Center has been established at the Norwegian School of Sport Sciences through generous grants from the Royal Norwegian Ministry of Culture and Church Affairs, the South-Eastern Norway Regional Health Authority, the International Olympic Committee, the Norwegian Olympic Committee & Confederation of Sport and Norsk Tipping AS.

Competing interests None.

Ethics approval Regional Committee for Medical Research Ethics, and the Norwegian Social Science Data Services.

Provenance and peer review Not commissioned; externally peer reviewed.

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V

Lower incidence of arm-to-head contact incidents with stricter interpretation of the Laws of the Game in Norwegian male professional football

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Received 28 June 2012
Revised 29 November 2012
Accepted 5 December 2012
Published Online First 11 January 2013

To cite: Bjørneboe J, Bahr R, Dvorak J, *et al. Br J Sports Med* 2013;**47**:508–514.

ABSTRACT

Background Video analyses reveal that the rate of incidents with a propensity for injury caused by opponent-to-player contact has increased by about 50% from 2000 to 2010 in Norwegian male professional football. The aim of the study was to assess whether a stricter interpretation of the Laws of the Game (red cards for high elbows in heading duels and for late/two foot tackles) could reduce the potential for injuries in Norwegian male professional football.

Methods A preintervention/postintervention design was employed, where the rate of incidents and injuries from the 2010 season (pre) was compared to the 2011 season (post). An incident was recorded if the match was interrupted by the referee, and the player lay down for more than 15 s, and appeared to be in pain or received medical treatment. Time-loss injuries were recorded by the medical staff of each club.

Results A total of 1421 contact incidents were identified, corresponding to a rate of 92.7 (95% CI 86.0 to 99.4) in the 2010 season and 86.6 (95% CI 80.3 to 99.4) in the 2011 season, with no difference between the two season. We found a reduction in the incidence of total head incidents (rate ratio (RR) 0.81, 95% CI 0.67 to 0.99), and head-incidents caused by arm-to-head contact (RR 0.72, 95% CI 0.54 to 0.97). We found no difference in tackling characteristics or contact injury rate.

Conclusions We found no significant differences in the overall rate of incidents after the introduction of stricter rule enforcement. However, the rate of head and arm-to head incidents was lower in the 2011 season.

INTRODUCTION

The risk of injury during football matches is 1000 times higher than high-risk industrial occupations,[1] with a time-loss injury incidence in male professional football between 20.3 and 34.8 injuries per 1000 player-match hours.[2–7] A recent study from Norwegian professional football documented an increased incidence of acute match injuries from 2002 to 2007.[8]

Medical staff injury registration has established that between 44% and 59% of all acute match injuries at the club level are caused by player-to-player contact.[3 7 9 10] Previous studies utilising video analysis to examine the mechanisms of injury in football have found that the most common causes of ankle injuries are tackles from the side, late tackles, two-footed tackles and tackles to the weight-bearing limb.[11–13] Arm-to-head contact is the most common cause of head injuries in male professional football.[14] Furthermore, recent video analyses revealed a 50% increase in the rate of incidents due to opponent-to-player contact from 2000 to 2010 in Norwegian male professional football.[15]

Video analyses of incidents leading to injuries in Fédération Internationale de Football Association (FIFA) tournaments showed that the match referee identified 47% of all injuries, and 40% of head injuries as foul play.[16] A study in Norwegian professional football concluded that most referee decisions were correct according to the Laws of the Game, but that there might be a need for more strict interpretation of the Laws of the Game in order to protect players from dangerous play.[17] The need for a reduction of foul play to reduce injury rates in football has therefore been emphasised.[17 18] As a consequence, The International Football Association Board gave referees the authority to severely sanction fouls that were recognised to be injurious, such as intentional elbows to the head.[19] After this, the incidence of match injuries was significantly lower in the 2010 FIFA World Cup for men compared to the mean incidence found in the three previous World Cups.[20] However, the effect of rule changes and their interpretation have neither been evaluated through prospective injury surveillance systems nor through video analysis, a key element missing in the current sport injury prevention research portfolio.[21]

Therefore, the aim of this study was to assess whether a stricter interpretation of the Laws of the Game could reduce the potential for injuries in Norwegian male professional football.

MATERIALS AND METHODS

Study design

This was a prospective study where we collected videotapes of league matches and injury information prospectively from the same matches prospectively during the 2010 and 2011 seasons to evaluate the effect of stricter rule enforcement by referees. We employed a preintervention/postintervention design, where the rate of incidents and injuries from the 2011 season (post) was compared to 2010 season data (pre).

Implementation of stricter rule enforcement

During the autumn of 2010 the Football Association of Norway (NFF) and the Norwegian Professional League Association (NTF) met with the project group from the Oslo Sports Trauma Research Center (OSTRC) and members of FIFA-Medical Assessment and Research Centre (F-MARC) to discuss the implementation of stricter rule enforcement in 2011 in the Norwegian male professional league (Tippeligaen).

Video recordings of incidents and injuries from the 2010 season were analysed and refereeing guidelines were agreed upon according to FIFA regulations. This involved sanctioning of two-foot tackles as well as tackles with excessive force and intentional high elbow with an automatic red card. A total of 15 referees and 25 assistant referees were familiarised with the stricter rule enforcement in meetings at the end of the 2010 season and in a training camp in January 2011.

The plans for stricter rule enforcement were introduced to each of the teams in meetings with referees appointed for the 2011 season. During these 1 h meetings the stricter interpretation of the rules was introduced through video clips, lectures and discussions. After informing the players, the study group and the Head of Refereeing in the Football Association of Norway held a similar meeting for the media. We also organised a press conference which included a high-profile player, manager and FIFA representative a week prior to the start of the season to inform the public.

Video analysis

An 'incident' was said to occur if the match was interrupted by the referee, the player stayed down for more than 15 s, and appeared to be in pain or received medical treatment. We did not include incidents caused by muscle cramps. Each incident was classified according to predetermined criteria: the cause (opponent-player contact, teammate-player contact, ball-player contact or non-contact), body location involved. A duel was defined as a situation where two opponents challenged each other for ball possession; duels were classified as heading duel, tackling duel or other duel (screening or running). We also categorised the referee's decision (no foul, foul for, foul against) and the referees sanction (no sanction, yellow card, red card). In cases where the referee played 'the advantage rule' the decision and sanction was classified depending on the activity of the downed player and the referees sanction. In addition, incidents affecting the head were classified by cause (head-to-head, arm-to-head, trunk-to-head, leg-to-head and in addition head-to-ground/ball/object were listed as head-to-other).

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

In addition, we conducted a video analysis of all player-to-player contact situations between players from opposing teams in 32 matches, irrespective of the consequence of the contact. A contact situation was said to occur when there was body contact between two players from opposing teams. We included situations where the players were challenging for ball possession. To select which 16 games to analyse in the two seasons a random draw was made using to bowls with a ball for each team, continuing the draw until we had picked one home match and one away match for each team. We registered the type of duel (tackling, heading or other). For heading duels we recorded the type of contact between the two opponents (trunk-trunk, head-head, arm-head and leg-head).

Injury registration

The study population included players with a first-team contract with one of the 16 clubs in the Norwegian male professional league (Tippeligaen). Prior to the 2010 season, the methodology of the UEFA injury study was implemented in the Norwegian professional football league.[7] An injury was registered if the player was unable to take fully part in football activity at least one day beyond the day of injury.[22] The player was considered injured until declared fit for full participation in training and available for match selection by the medical staff. Individual player exposure in training and matches was registered by the clubs medical staff on a standard exposure form.

The injury form was designed according to the consensus statement,[22] including information about the date of injury, the cause of injury (contact or non-contact), the type of activity (match or training) in which the injury occurred, injury location and injury history. We categorised injuries into four severity categories according to the duration of absence from match and training sessions: minimal (1–3 days); mild (4–7 days); moderate (8–28 days) and severe (>28 days).

A member of the club medical staff conducted the prospective injury registration. The club license for Norwegian male professional football clubs requires that a chartered physiotherapist is available for the club and they usually attend all organised team activities, that is, all training sessions and matches. We collected the forms on a monthly basis and, if needed, we followed up with reminder text messages and phone calls. If information was missing from the injury cards or we discovered any other inconsistencies, a member of the study group contacted the medical staff for clarification. Twelve teams participated in the injury registration during the 2010 season and 14 teams in the 2011 season.

The Regional Committee for Medical Research Ethics, Region Øst-Norge and the Norwegian Social Science Data Services approved the study.

Outcome measures and statistics

The primary outcome measure was the overall rate of contact incidents before and after the introduction of stricter rule enforcement in the 2011 season. Secondary outcome measures were the rate of head contact incidents, ankle contact incidents and contact injuries. Our hypothesis was that stricter rule enforcement by the referees would lead to a reduction in the number of incidents, especially head and ankle incidents.

We calculated our sample size using a formula for cohort studies with Poisson outcomes[23] based on incident rates in the 2000 season, that is, 75 incidents/1000 player-match hours.[24] An estimated total of 630 incidents per season would provide an acceptable power of 0.9 at the 5% significant level to detect a 30% reduction in the number of incidents. Correspondingly, an estimate of 180 ankle and head incidents per season would enable us to detect an effect size of 50% for these two categories. Based on an expected incidence of 18 acute injuries/1000 player-match hours, with 13 participating clubs and assuming that approximately 50% of all injuries would be contact injuries, we expected a total of 50 recorded match contact injuries each season. Thus, we would need a decrease in contact injury incidence of 70% after the introduction of stricter rule enforcement

Table 1 Characteristics of incidents (n=1721) from video analysis of all games (n=240 each season)

	2010		2011		2010 vs 2011
	Incidents	Rate	Incidents	Rate	Rate ratio
Contact opponent	734	92.7 (86.0 to 99.4)	687	86.7 (80.3 to 93.2)	0.94 (0.84 to 1.04)
Contact teammate	28	3.5 (2.2 to 4.8)	28	3.5 (2.2 to 4.8)	1.00 (0.59 to 1.69)
Non-contact	68	8.6 (6.5 to 10.6)	91	11.5 (9.1 to 13.9)	1.34 (0.98 to 1.83)
Contact ball	32	4.0 (2.6 to 5.4)	45	5.7 (4.0 to 7.3)	1.41 (0.89 to 2.21)
Other	6	0.8 (0.2 to 1.4)	2	0.3 (−0.1 to 0.6)	0.33 (0.07 to 1.65)

Rate is reported as the number of incidents per 1000 player-match hours with 95% CI. Rate ratios between the 2010 and 2011 seasons are shown with 95% CI, with the 2010 season as the reference group.

in Norwegian professional football to have a power of 0.9 and a 5% significance level.

Results are presented as the rate of incidents and injuries (injuries or incidents/1000 player-match hours). We used a z test and the 95% CI based on the Poisson model to compare the rate ratio between the 2010 season and 2011 season. Rate ratios are presented with the 2010 season as the reference group. Categorical variables were compared using a χ^2 test. A two-tailed p value of less than ≤ 0.05 was regarded as significant.

RESULTS

Incidents

During the two seasons all 240 matches were analysed, leading to 7920 player-match hours/season. A total of 1721 match incidents were identified during the two seasons, 868 in 2010 and 853 in 2011. The corresponding overall incident rate was 109.6/1000 player-match hours of exposure (95% CI 102.3 to 116.9) in the 2010 season and 107.7 (95% CI 100.5 to 114.9) in the 2011 season, with no difference between the two season (rate ratio: 0.98, 95% CI 0.89 to 1.08). No differences were observed in the rate of opponent-to-player contact, non-contact incidents, teammate-to-player contact or ball-to-player contact (table 1).

Heading and tackling characteristics

We did not detect any difference in the rate of incidents caused by opponent-to-player contact, not for heading nor tackling duels. We found a lower rate of head incidents in the 2011 season compared to the 2010 season (table 2). We found a reduced incidence of arm-to-head situations in the 2011 season. No differences were found in the incidence of other mechanisms for all head incidents (table 3) or during heading duels.

Of the 861 tackling incidents captured during the two seasons, the downed player was passive in 724 (84%) and active in 137 (16%) of the duels. The characteristics of the 724 passive tackling situations are listed in table 4. We found a reduced incident rate of passive tackles from the front. We found no differences for passive tackle actions, tackling mode, tackling timing or tackles with ball contact. For active tackling duels we found an increased rate of sliding tackles and tackles with ball contact prior to opponent contact in the 2011 season.

Decision of the referee

The referee decisions for the 1421 incidents are characterised in table 5. We found that a higher proportion of passive tackling duels in the 2011 season resulted in a free-kick being awarded (p=0.01). We found no difference in the percentage of free-kicks awarded for all opponent-to-player contact incidents, arm-to-head incidents or arm-to-head incidents in heading duels. We found no difference in the referee's sanctioning of incidents between the two seasons (table 5).

Player-to-player contact situations

During the 32 matches analysed in their entirety, 3547 situations with player-to-opponent contact in duels were identified, 1739 in the 2010 season and 1808 in the 2011 season. The corresponding overall rate of contact situations was 3294/1000 exposure h (95% CI 3139 to 3448) in the 2010 season and

Table 2 Characteristics of incidents due to opponent-to-player contact (n=1421) from video analysis of all games (n=240 each season)

	2010		2011		2010 vs 2011
	Incidents	Rate	Incidents	Rate	Rate ratio
Duel type					
Heading duel	215	27.1 (23.5 to 30.8)	177	22.3 (19.1 to 25.6)	0.82 (0.68 to 1.00)
Tackling duel	437	55.2 (50.0 to 60.4)	424	53.5 (48.4 to 58.6)	0.97 (0.85 to 1.11)
Other duel	82	10.4 (8.1 to 12.6)	86	10.9 (8.6 to 13.2)	1.05 (0.78 to 1.42)
Body location					
Head/neck	226	28.5 (24.8 to 32.3)	184	23.2 (19.9 to 26.6)	0.81 (0.67 to 0.99)
Upper extremity	16	2.0 (1.0 to 3.0)	16	2.0 (1.0 to 3.0)	1.00 (0.50 to 2.00)
Trunk	91	11.5 (9.1 to 13.9)	108	13.6 (11.1 to 16.2)	1.18 (0.90 to 1.57)
Lower-extremity					
Thigh	39	4.9 (3.4 to 6.5)	56	7.1 (5.2 to 8.9)	1.44 (0.95 to 2.16)
Knee	49	6.2 (4.5 to 7.9)	39	4.9 (3.4 to 6.5)	0.80 (0.52 to 1.21)
Lower leg/ankle	313	39.5 (35.1 to 43.9)	284	35.9 (31.7 to 40.0)	0.91 (0.77 to 1.07)

Incident rate is reported per 1000 player-match hours with 95% CI. Rate ratios between the 2010 and 2011 seasons are shown with 95% CI, with the 2010 season as the reference group.

Table 3 Characteristics of head incidents due to opponent-to-player contact (n=410) from video analysis of all games (n=240 each season)

	2010		2011		2010 vs 2011
	Incidents	Rate	Incidents	Rate	Rate ratio
All head incidents (n=410)					
Head-to-head	74	9.3 (7.2 to 11.5)	70	8.8 (6.8 to 10.9)	0.95 (0.68 to 1.31)
Arm-to-head	109	13.8 (11.2 to 16.3)	79	10.0 (7.8 to 12.2)	0.72 (0.54 to 0.97)
Shoulder-to-head	10	1.3 (0.5 to 2.0)	11	1.43 (0.65 to 2.2)	1.10 (0.47 to 2.59)
Trunk-to-head	10	1.3 (0.5 to 2.0)	7	0.9 (0.2 to 1.5)	0.70 (0.27 to 1.84)
Leg-to-head	21	2.7 (1.5 to 3.8)	16	2.0 (1.0 to 3.0)	0.76 (0.40 to 1.46)
Otder-head	2	–	1	–	–
Heading duel (n=286)					
Head-to-head	68	8.6 (6.5 to 10.6)	66	8.3 (6.5 to 10.3)	0.97 (0.69 to 1.36)
Arm-to-head	84	10.6 (8.3 to 12.9)	47	5.9 (4.2 to 7.6)	0.56 (0.39 to 0.80)
Shoulder-to-head	6	0.8 (0.2 to 1.4)	3	0.4 (0.0 to 0.8)	0.50 (0.13 to 2.00)
Trunk-to-head	2	0.3 (−0.1 to 0.6)	4	0.5 (0.0 to 1.0)	2.00 (0.37 to 10)
Leg-to-head	3	0.4 (0.0 to 0.8)	2	0.3 (−0.1 to 0.6)	0.67 (0.11 to 4.00)
Otder-head	0	–	1	–	–

Rate is reported per 1000 player-match hours with 95% CI. Rate ratios between the 2010 and 2011 seasons are shown with 95% CI, with the 2010 season as the reference group.

3424 (95% CI 3266 to 3582) in the 2011 season; thus, no significant difference between the two seasons was found (RR 1.04, 95% CI 0.97 to 1.11). We also did not detect any difference in the incidence of heading duels or tackling duels between the two seasons (table 6).

Injury registration

A total of 12 763 player-match hours were registered during the two seasons; 5850 (46%) in 2010 and 6912 (54%) in 2011. A total of 202 acute injuries were recorded, of which 99 in 2010 and 103 in 2011, corresponding to an overall acute injury incidence of 16.9/1000 player-match hours (95% CI 13.6 to 20.3) in 2010 and 14.9 (95% CI 12.0 to 17.8) in 2011. We found no difference in overall injury incidence between the 2010 season and the 2011 season (rate ratio: 0.88, 95% CI 0.67 to 1.16). No differences were observed for the incidence of contact or non-contact acute match injuries between the 2010 season and the 2011 season. We found a reduced rate of acute contact injuries of minimal severity. No difference was detected between the two seasons for injury type and injury location (table 7).

Of the 82 acute contact injuries reported to have occurred during league matches, 47 (57%) were identified through video analysis. Of these 47 injuries, 9 (19%) were classified as

Table 4 Tackling characteristics for incidents where the involved player was passive (n=724) from video analysis of all games (n=240 each season)

	2010		2011		2010 vs 2011
	Incidents	Rate	Incidents	Rate	Rate ratio
Tackle direction					
Front	139	17.6 (14.6 to 20.5)	106	13.4 (10.8 to 15.9)	0.76 (0.59 to 0.98)
Side	164	20.7 (17.5 to 23.9)	186	23.5 (20.1 to 26.9)	1.13 (0.92 to 1.40)
Back	75	9.5 (7.3 to 11.6)	54	6.8 (5.0 to 8.6)	0.72 (0.51 to 1.02)
Tackle action					
One-foot	333	42.0 (37.5 to 46.4)	300	37.9 (33.6 to 42.2)	0.90 (0.77 to 1.05)
Two-footed	11	1.4 (0.6 to 2.2)	4	0.5 (0.0 to 1.0)	0.36 (0.11 to 1.14)
Upper body	29	3.7 (2.3 to 5.0)	31	3.9 (2.5 to 5.3)	1.07 (0.64 to 1.77)
Other	5	0.6 (0.1 to 1.2)	11	1.4 (0.6 to 2.2)	2.20 (0.76 to 6.33)
Tackling mode					
Feet	208	26.3 (22.7 to 29.8)	197	24.9 (21.4 to 28.3)	0.95 (0.78 to 1.15)
Sliding in	166	21.0 (17.8 to 24.1)	142	17.9 (15.0 to 20.9)	0.86 (0.68 to 1.07)
Other	4	0.5 (0.0 to 1.0)	7	0.9 (0.2 to 1.5)	1.75 (0.51 to 5.98)
Tackling timing					
Early	206	26.0 (22.5 to 29.9)	196	24.7 (21.3 to 28.2)	0.95 (0.78 to 1.16)
Late	172	21.7 (18.5 to 25.0)	150	18.9 (15.9 to 22.0)	0.87 (0.70 to 1.09)
Contact ball					
Prior to opponent	61	7.7 (5.8 to 9.6)	64	8.1 (6.1 to 10.1)	1.05 (0.74 to 1.49)
After opponent	40	5.1 (3.5 to 6.6)	43	5.4 (3.8 to 7.1)	1.08 (0.70 to 1.65)
No ball contact	277	35.0 (30.9 to 39.1)	239	30.2 (26.4 to 34.0)	0.86 (0.72 to 1.02)

Rate is reported per 1000 player-match hours with 95% CI. Rate ratios between situations in the 2010 and 2011 seasons are shown with 95% CI, with the 2010 season as the reference group.

Table 5 Referee decision for different incident types caused by opponent-to-player contact from video analysis of all games (n=240 each season)

	2010		2011		2010 vs 2011
	Incidents	Percentage	Incidents	Percentage	p Value
Opponent-to-player contact (n=1421)					
Free kick	379	52	367	53	0.50
Sanctioned	128	34	114	31	0.38
Passive tackling incidents (n=724)					
Free kick	253	67	262	76	0.01
Sanctioned	108	43	103	39	0.44
Arm-to-head contact (n=188)					
Free kick	38	35	30	38	0.66
Sanctioned	6	16	4	13	0.89
Arm-to-head contact in heading duels (n=131)					
Free kick	34	41	17	36	0.63
Sanctioned	5	15	1	6	0.36

Proportions were compared using a χ^2 test.

minimal, 13 (28%) as mild, 13 (28%) as moderate and 12 (26%) as severe. Of the 35 acute contact injuries not identified on video, 10 (29%) were classified as minimal, 10 (29%) as mild, 13 (37%) as moderate and 2 (5%) as severe.

DISCUSSION

This is the first study to evaluate the effect of stricter interpretation of the Laws of the Game on the risk of match injury in male professional football. The main finding of the study was that there was a reduction in the rate of head incidents, and head-incidents caused by arm-to-head contact. We found, however, neither a difference in the overall incident rate between the two seasons, nor in the rate of tackling incidents.

Ideally, a reduction of contact injuries would serve as endpoint. However, with an expected total of 50 contact injuries, the effect of the stricter rule enforcement would have required a 70% decrease in injury incidence in order to detect it. We therefore chose incident rate as our primary outcome and measure of injury risk. The 15-s cut-off was chosen because that was thought to be long enough to avoid incidents where players intentionally stayed down either to rest, simulate an injury or to delay playing time. However, only 47 of the 1421 (3%) incidents resulted in an injury recorded by the medical staff. In addition, video analysis did not capture 35 of the injuries recorded by the medical staff. Despite this, we do believe incidents serve as a surrogate measure of injury risk, as the incidents represents events with a propensity for injury.[12 24 25] There is also a possibility of a type II error resulting from small numbers, especially when comparing incidences in subcategories of injuries and incidents, such as for a location, mechanism, type or severity.

With an RCT not being possible, a pre-/post-intervention design was employed, where data from the 2011 season was compared to 2010 season data. There have been no other changes in the Norwegian male professional league system or style of play that we can think of which could explain the observed reduction in head incidents, or head incidents caused by arm-to-head contact.

We conducted a separate video analysis where 32 games were analysed for all situations involving opponent contact. In this analysis we found no difference in the overall incidence of player-to-player contact between the two seasons. We could not detect any difference in the incidence of heading or tackling duels, nor the incidence of arm-to-head contact in heading duels. Thus, there is no reason to assume that the reduced incidence of head incidents and head incidents caused by arm-to-head contact was due to an overall change in the style of play or intensity of play in matches from the 2010 to the 2011 season.

Previous studies on injury mechanisms in football have found that most ankle and head injuries are caused by player-to-player contact.[11 13 14] The most common cause of head injuries is heading duels, with subsequent arm-to-head contact or head-to-head contact.[12 14] Incidents and injuries caused by head-to-head contact are normally not deliberate, while arm-to-head incidents sometimes are. Therefore, we introduced a stricter rule interpretation, explicitly sanctioning intentional high elbows with an automatic red card, to reduce the rate of head incidents. We found a reduced frequency of contact head incidents. It is therefore encouraging that the incidence of arm-to-head contact incidents was reduced after the introduction of stricter rule enforcement.

For ankle injuries, the most common cause of contact injury is being tackled to the weight bearing limb, involving lateral and medial forces and the tackler staying on his feet.[11–13] Therefore, we focused on the sanctioning of two-foot tackles as well as tackles with excessive force with an automatic red card. Still, we found no difference in characteristics for passive tackles between the two seasons, indicating that the intervention did not change player behaviour in these situations. Correspondingly, we were not able to reduce the rate of lower leg/ankle incidents.

One question is of course whether the referees actually did award free kicks and sanctions as intended, with a straight red card for two-foot tackles, tackles with excessive force and intentional high elbows. We found that a free-kick was awarded in a higher proportion of the passive tackling incidents in the 2011

Table 6 Characteristics of player-to-player contact situations (n=3547) from video analysis of 32 randomly picked matches

	2010		2011		2010 vs 2011
	Situations	Rate	Situations	Rate	Rate ratio
Duel type (n=3547)					
Heading duel	816	1546 (1439 to 1652)	818	1549 (1443 to 1655)	1.00 (0.91 to 1.11)
Tackling duel	651	1233 (1138 to 1328)	710	1344 (1246 to 1444	1.09 (0.98 to 1.21)
Other duel	272	515 (454 to 576)	280	530 (468 to 592)	1.03 (0.87 to 1.22)

Situation rate is reported per 1000 player-match hours with 95% CI. Rate ratios between the 2010 and 2011 seasons are shown with 95% CI, with the 2010 season as the reference group.

Table 7 Characteristics of acute match injuries (n=202) recorded through the injury surveillance system

	2010		2011		2010 vs 2011
	Injuries	Rate	Injuries	Rate	Rate ratio
Contact opponent	44	7.5 (5.3 to 9.7)	38	5.5 (3.7 to 7.2)	0.73 (0.47 to 1.13)
Contact teammate	2	–	1	–	–
Non-contact	52	8.9 (6.5 to 11.3)	61	8.8 (6.6 to 11.0)	0.99 (0.69 to 1.44)
Contact ball	1	–	3	–	–
Contact injuries (n=82)					
Injury type					
Fracture	3	–	2	–	–
Joint and ligament	18	3.1 (1.7 to 4.5)	14	2.0 (1.0 to 3.1)	0.66 (0.33 to 1.32)
Concussion	3	–	4	–	–
Contusion	18	3.1 (1.7 to 4.5)	18	2.6 (1.4 to 3.8)	0.85 (0.44 to 1.63)
Other	2	–	0	–	–
Body location					
Head/neck	5	0.9 (0.1 to 1.6)	7	1.0 (0.3 to 1.8)	1.19 (0.38 to 3.73)
Upper extremity	3	–	5	–	–
Trunk	1	–	6	–	–
Lower extremity					
Hip/groin	1	–	2	–	–
Thigh	9	–	3	–	–
Knee	10	1.7 (0.6 to 2.8)	5	0.7 (0.1 to 1.4)	0.42 (0.15 to 1.24)
Lower leg	3	–	3	–	–
Ankle	8	1.4 (0.4 to 2.3)	6	0.9 (0.2 to 1.6)	0.64 (0.22 to 1.83)
Foot	4	–	1	–	–
Time loss					
Minimal	15	2.6 (1.3 to 3.9)	4	0.6 (0.0 to 1.1)	0.23 (0.08 to 0.68)
Mild	11	1.9 (0.8 to 3.0)	12	1.7 (0.8 to 2.7)	0.92 (0.41 to 2.09)
Moderate	10	1.7 (0.6 to 2.8)	16	2.3 (1.2 to 3.4)	1.35 (0.62 to 2.98)
Severe	8	1.4 (0.4 to 2.3)	6	0.9 (0.2 to 1.6)	0.64 (0.22 to 1.83)

Rate is reported per 1000 h of match exposure (with 95% CI). Rate ratios between injuries in the 2010 and 2011 season are shown with 95% CI, with the 2010 season as the reference group.
–, Due to small numbers statistics were not computed.

season; however, no difference was found in the sanctioning. We were not able to observe any difference in the decision-making or the sanctioning of arm-to-head incidents.

We had no referee panel to evaluate the decisions of the referees; thus, we are not able to assess whether the decisions were correct according to expert opinion. Fuller *et al*[12] found that referees identified only 40% of head/neck injuries as foul play during FIFA tournaments.

During the 2010 and 2011 season, all straight red cards (4) were given for tackling incidents and no straight red cards were given for arm-to-head contact. This might indicate that it is more difficult for the referees to recognise arm-to-head incidents and that the reduction in head incidents and arm-to-head incidents was due to changes in player behaviour.

Since the 2006 season, the fourth official has become an integral part of the officiating team and the role is to advise the match referee. In addition, UEFA has in recent tournaments introduced two goal-line officials to ensure that the Laws of the Game are upheld, especially within the penalty box. The expansion of the refereeing team may help to ensure stricter rule enforcement.

In an assessment of player error as an injury causation factor in international football it was found that human error during tackling, inadequacies in the Laws of the Game and/or their application by match referees were equally responsible for the high levels of injury observed.[26] In a study of psychological characteristics of football players Junge *et al*[27] found that players have insufficient respect for the Laws of the Game and its regulation. In addition, nearly all players were ready to commit a 'professional foul' if necessary and a majority stated that concealed fouls were a part of the game. However, we have not evaluated player attitudes to stricter rule enforcement, but it is possible that the increased focus on the potential of injury through arm-to-head contact and the stricter rule enforcement have changed their attitude towards safer behaviour in heading duels.

The injury incidence in Norwegian male professional football is lower than the Champions League level.[7 8] In addition, epidemiological studies on the risk of injury in male professional football have indicated that the injury rate is slightly higher during international matches.[5 7 20 24 28–31] Video analysis of injuries and incidents with a high potential of injury has not been evaluated in leagues with a higher injury rate compared to Tippeligaen. We therefore suggest that a similar approach to stricter rule enforcement is included and evaluated in a league or tournament with higher injury risk.

In summary, we found no differences in the overall rate of incidents after the introduction of sanctioning of two-foot tackles as well as tackles with excessive force and intentional high elbow with an automatic red card. However, the rate of head incidents caused by player-to-player contact and the rate of arm-to-head incidents was lower in the 2011 season after implementation of stricter rule enforcement.

What this study adds to existing knowledge

- Implementation of stricter rule enforcement was associated with a lower incidence of head-incidents caused by arm-to-head contact.

How might it impact on clinical practice in the near future

- Increased focus on the effect of rule changes and regulations on injury risk. It might also lead to implementation of stricter rule enforcement in other leagues and tournaments, in order to reduce the number of situations with a high injury potential.

Acknowledgements We would like to thank the players and the medical staff in Tippeligaen for their participation. We would also like to thank Svein Inge Børven and Kenneth Wilsgård for analysing 32 matches for all player-to-player contact.

Contributors JB, RB, JD and TEA contributed to study conception, design and development of the intervention. JB coordinated the study and managed all aspects, including data collection. JB conducted and initialised the data analyses, which were planned and checked with RB, JD and TEA. JB, RB and TEA wrote the first draft of the paper, and all authors contributed to the final manuscript. JB and TEA are guarantors. The contributing authors have made substantial contributions to the conception, design, analysis and interpretation of data, drafting of the article and have all given final approval of the current version and agree to its submission.

Funding This study was supported by grants from the FIFA Medical Assessment and Research Centre. The Oslo Sports Trauma Research Center has been established at the Norwegian School of Sport Sciences through generous grants from the Royal Norwegian Ministry of Culture and Church Affairs, the South-Eastern Norway Regional Health Authority, the International Olympic Committee, the Norwegian Olympic Committee & Confederation of Sport, and Norsk Tipping AS.

Competing interests None.

Provenance and peer review Not commissioned; externally peer reviewed.

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