Injuries in Football

Risk factors, injury mechanisms, team performance and prevention

Dissertation by

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Summary

The aims of this study were to investigate the injury risk in Icelandic elite male football, to study whether different factors could be identified as risk factors for injuries and to examine the relationship between team physical fitness, injuries and team performance. We also wanted to investigate the characteristics of incidents and injury situations, and the effectiveness of a video-based awareness program on the incidence of acute injuries.

Paper I: Before the 1991 competitive season started, 84 players from five teams were tested with regard to flexibility and mechanical stability of ankles and knees. They also answered a questionnaire about previous injuries. During the season injuries and player exposure during matches and training sessions were registered prospectively. The results showed a high incidence of acute injuries (33.0 ± 3.4 per 1000 match hours and 5.3 ± 1.0 per 1000 training hours), with hamstring strains and ankle sprains as the most frequent injury types. Recurrent injuries were also common. 44% of acute injuries occurred during contact with another player, where tackling was the most frequent injury mechanism. Significantly more injuries occurred on artificial turf than on grass or gravel. More injures occurred in medially unstable knees, but no correlation was found between preseason flexibility or ankle instability and injuries during the season.

Paper II: Just before the start of the 1999 competitive season players from 17 teams in the Icelandic elite league and first division performed a series of testing procedures and answered a questionnaire about previous and recurrent injures. The testing procedures included peak O_2 uptake tests, body composition tests, leg extensor power tests, jump tests, flexibility tests, as well as ankle and knee stability tests. During the competitive season injuries were recorded prospectively, as well as the match and training exposure. The results showed that older players were at higher risk of injury in general ($OR=1.1$ per year, $p=0.05$). Significant risk factors for hamstring strains were increased age ($OR=1.4$ per year, $p<0.001$) and previous hamstring strains ($OR=11.6$, $p<0.001$). For groin strains the risk factors were previous groin strains ($OR=7.3$, $p=0.001$) and decreased range of motion for hip abduction ($OR=0.9$ per one degree, $p=0.05$). Previous injury was also identified as a risk factor for knee ($OR=4.6$, $p=0.002$) and ankle sprains ($OR=5.3$, $p=0.009$).

Paper III: Team average physical fitness from the preseason tests during the 1999 season was compared with team success (final league standing) during the following competitive season. Physical fitness was also compared between different playing positions. The results showed a significant relationship between team average jump height and team success (counter movement jump: $p=0.009$, standing jump: $p=0.012$). The same trend was also found for leg extension power ($p=0.097$), body composition ($p=0.07$), and total number of injury days per team ($p=0.09$). Goalkeepers demonstrated different fitness characteristics from outfield players, while only minor differences were observed between defenders, midfield players and attackers.

Paper IV: Videotapes from 52 matches from the Icelandic elite league were reviewed during the 1999 competitive season. Incidents were recorded when the match was interrupted by the referee because of a suspected injury. All incidents and the events leading up to them were copied to a master tape and analyzed further. Of 95 incidents recorded, 28 led to time-loss injury as registered by the team physical therapists. In 93% of the incidents the attention of the exposed player was focused away from the opponent challenging him for ball possession and in 66% of the incidents the exposed player had low degree of ball control. Three compound injury mechanisms were found to be responsible for 57% of all incidents: a) Breakdown attacks with tackling from the side or the front with the attention focused on the ball (24%), b) Defensive player in a tackling duel with his attention focused on the ball or with low degree of ball control (20%), c) Heading duels with the attention focused on the ball in the air (13%).

Paper V: 17 of 20 teams in the Icelandic elite league and first division were block-randomized to an intervention or a control group. Just before the start of the 2000 competitive season the intervention teams were visited with an intervention program that included a 15 min presentation of injury risks in football and typical injury mechanisms. Then the players worked together in pairs and analyzed 12 video sequences selected from the three most common injury mechanisms found during the previous season. The players were asked to develop preventive strategies for these 12 playing situations. During the season injuries, as well as training and match exposure were registered prospectively. The results showed no difference in injury incidence between the intervention and control groups or between the intervention group and the same teams the year before.

Key Words: Football, soccer, injuries, risk factors, physical performance, maximal O_2 uptake, jumping ability, leg power, flexibility, body composition, match analysis, video analysis, Football incident analysis, injury mechanisms, intervention, prevention.

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Reykjavík, May 2004

Árni Árnason

List of papers

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

I. Arnason A, Gudmundsson A, Dahl HA, Johannsson E. Soccer injuries in Iceland. Scand J Med Sci Sports. 6: 40-45, 1996.

II. Arnason A, Sigurdsson SB, Gudmundsson A, Holme I, Engebretsen L, Bahr R. Risk factors for injuries in football. Am J Sports Med. 32: 5S-16S, 2004.

III. Arnason A, Sigurdsson SB, Gudmundsson A, Holme I, Engebretsen L, Bahr R. Physical fitness, injuries, and team performance in soccer. Med Sci Sports Exerc. 36: 287-285, 2004.

IV. Arnason A, Tenga A, Engebretsen L, Bahr R. A prospective video-based analysis of injury situations in elite male football – Football incident analysis. Am J Sports Med. In press 2004.

V. Arnason A, Engebretsen L, Bahr R. No effect of a video-based awareness program on the rate of soccer injuries. Am J Sports Med. In press 2004.

Abbreviations

ACL	Anterior cruciate ligament
B	Unstandardized beta (unstandardized regression coefficient)
BMI	Body mass index
CI	Confidence interval
CMJ	Countermovement jump
CMJ one	Countermovement jump on one leg
CV%	Coefficient of variance
F-MARC Bricks	A standardized test battery of football specific tests, conducted by the FIFA Medical Assessment and Research Centre
FIA	Football incident analysis
OR	Odds ratio
ROM	Range of motion
SD	Standard deviation
SEM	Standard error of the mean
SJ	Standing jump

Introduction

Football is one of the most widespread sports in the world (Tumilty 1993; Inklaar 1994a). In Iceland football is also the largest organized sport, and during the year 2000, 5.7% of the Icelandic population was registered as football players in different football clubs (The National Olympic and Sport Association of Iceland, personal communication, January 2003).

When studying injuries in football, three main questions are of interest: First, what is the magnitude of the problem? Second, what are the causes of injuries? Third, what can we do to prevent injuries? Many studies deal with the first question, but fewer studies have been carried out on the second and especially the third question. The present study was carried out to increase our understanding of risk factors and injury mechanisms in football and try out preventive measures of injures in football.

The magnitude of the problem

Incidence of injuries

Injuries in football are common compared to most other types of sport (de Loes 1995) and account for 30-56% of all sport-related injuries in some European countries (Hoy et al. 1992; de Loes 1995). Although this is partly due to the popularity of the sport, the injury incidence (injuries per 1000 hours of match, training or both match and training) is also high as shown in Table 1. The incidence rates for adult male players in different studies vary between 11.9 and 35.3 injuries/1000 match hours and 1.5-7.6 injuries/1000 training hours. This variation can be caused by different study populations, age and level of play as well as differences in research design, or the quality of the exposure data and injury registration. Studies on female football players have shown the injury incidence rates to be within the range found among male players (Engstrom et al. 1991; Ostenberg and Roos 2000). Most studies show that injury incidence in adolescents increases with age (Hoff and Martin 1986; Backous et al. 1988; Inklaar et al. 1996; Hawkins and Fuller 1999). Some studies also estimate injury incidence for particular type of injuries. Ekstrand and Tropp (Ekstrand and Tropp 1990) found that the incidence of ankle sprains in the Swedish divisions I-VI was 1.7 ± 0.9 - 2.0 ± 0.8/1000 hours of exposure (match and training combined). Ekstrand and Hilding (Ekstrand

and Hilding 1999) found that the incidence of groin injuries in the Swedish IV division was 0.8/1000 hours of exposure (match and training combined). Drawer & Fuller (Drawer and Fuller 2002a) compared the injury risk of professional football players to injury risk in construction, manufacturing and service industries. They concluded that injury risk among professional football players was much higher than in industry, and unacceptably high compared to work-based risk criteria used by the Health and Safety Executive in the United Kingdom.

Table 1. Epidemiological studies on incidence of injuries in football.

Authors (publ. year)	**Number of players (age)**	**Study period**	**Injuries / 1000 hours**		
			Match	**Training**	**Total**
Professional or elite male players					
Morgan and Oberlander (2001)	237 (18-38y)	1 season	35.3	2.9	6.2
Hawkins and Fuller (1999)	108	3 seasons	25.9	3.4	
Luthje et al. (1996)	263 (17-35y)	1 season	16.6	1.5	
Poulsen et al. (1991)	19 (21-28y)	1 year	19.8	4.1	6.9
Engström et al. (1990)	64	1 season	13	3	5
Ekstrand and Tropp (1990)	135 Division 1 180 Division 2	1 year 1 year	21.8 ± 11.3 18.7 ± 8.0	4.6 ± 1.7 5.1 ± 1.7	8.6 ± 3.3 8.5 ± 3.2
Nielsen and Yde (1989)	34 (> 18y)	1 season	18.5	2.3	
Male players at lower divisions					
Inklaar et al. (1996)	245 (18-60y)	½ season	15.8 ± 3.4		
Poulsen et al. (1991)	36 (24-30y)	1 year	20.7	5.7	12.5
Ekstrand et al. (1983b)	180 (17-38y) Division 4	1 year	16.9 ± 7.3	7.6 ± 2.1	10.5 ± 3.0
Ekstrand and Tropp (1990)	144 Division 6	1 year	14.6 ± 6.1	7.5 ± 5.9	9.4 ± 2.7
Nielsen and Yde (1989)	59 (> 18y)	1 season	11.9	5.6	
Female players at various level					
Östenberg and Roos (2000)	123 (14-39 y)	1 season	14.3	3.7	
Engström et al. (1991)	41	1 year	24	7	12

Authors (publ. year)	Number of players (age)	Study period	Injuries / 1000 hours		
			Match	Training	Total
Adolescents					
Kakavelakis et al. (2003)	287 (12-15y)	1 season Boys only	5.6	3.3	4.0
Söderman et al. (2001a)	153 (14-20y)	1 season Girls only	9.1	1.5	4.4
Hawkins and Fuller (1999)	30	3 seasons Boys only	37.2	4.1	
Inklaar et al. (1996)	75 (13-14y) 78 (15-16y) 79 (17-18y	½ season ½ season ½ season Boys only	12.8 ± 3.5 16.1 ± 5.0 28.3 ± 4.9		
Nielsen and Yde (1989)	30 (16-18y)	1 season Boys only	14.4	3.6	
Backous et al. (1988)	1 139 (6-17y)	Summer football camp			Boys: 7.3 Girls: 10.6
Mæhlum et al. (1986)	1 016 teams (<12-18y)	Norway Cup Tournament	Boys: 8.9 Girls: 17.6		
Schmidt-Olsen et al. (1985)	6 600 (9-19y)	Tournament	Boys: 7.4 Girls: 17.6		
Nilsson and Roaas (1978)	25 000 (11-18y)	Tournament	Boys: 14 Girls: 32		

Type and location of injuries

In numerous studies the type, location and severity of injuries in football have been investigated (Ekstrand and Gillquist 1982; Ekstrand et al. 1983a; Ekstrand and Gillquist 1983a; Ekstrand and Gillquist 1983b; Tropp et al. 1984; Nielsen and Yde 1989; Yde and Nielsen 1990; Ekstrand and Tropp 1990; Engstrom et al. 1990; Taimela et al. 1990b; Poulsen et al. 1991; Engstrom et al. 1991; Baumhauer et al. 1995; de Loes 1995; Luthje et al. 1996; Inklaar et al. 1996; Bjordal et al. 1997; Hawkins and Fuller 1999; Ostenberg and Roos 2000; Heidt, Jr. et al. 2000; Chomiak et al. 2000; Peterson et al. 2000; Hawkins et al. 2001; Junge et al. 2002; Woods et al. 2002; Kakavelakis et al. 2003). The definition of injury as well as the severity of injury, differs somewhat between studies, which makes exact comparisons difficult, but studies have shown that acute injuries represent 69-94% of all injuries in football, while 6-31% are overuse injuries (Ekstrand and Gillquist 1983a; Engstrom et al. 1991; Luthje et al. 1996; Ostenberg and Roos 2000). Previous studies indicate that the most common types of injuries in football are ligament sprains (19-55%), muscle strains (12-37%) and contusions (4-26%), while other types of injuries, such as fractures (3-7%) and dislocations (0-3%), are not as common. The most frequent injury locations are the ankle (11-36%), knee (14-33%), thigh (8-23%), groin (7-13%), foot (5-21%), lower leg (2-13%), back (2-11%) and head (1-4%) (Ekstrand et al. 1983a; Ekstrand and Gillquist 1983a; Ekstrand and Gillquist 1983b; Nielsen and Yde 1989; Yde and Nielsen 1990; Engstrom et al. 1990; Poulsen et al. 1991; Engstrom et al. 1991; Luthje et al. 1996; Inklaar et al. 1996; Hawkins and Fuller 1999; Ostenberg and Roos 2000; Peterson et al. 2000; Hawkins et al. 2001; Woods et al. 2002). Of specific injury types, most previous studies indicate that ankle sprains are the most common in football (Ekstrand and Gillquist 1983a; Yde and Nielsen 1990; Engstrom et al. 1991; Peterson et al. 2000; Woods et al. 2002). However, some recent studies show a higher proportion of hamstring strains than ankle or knee sprains (McGregor and Rae 1995; Hawkins and Fuller 1999; Hawkins et al. 2001).

Consequences of injuries

Usually the severity of injuries is estimated based on the duration of absence from matches and training sessions. As shown above, injuries are common in football and studies have shown that 11%-35% of injures are severe (lasted more than three or four weeks), and recurrent injuries are also common (Ekstrand and Gillquist 1983a; Nielsen and Yde 1989; Yde and Nielsen 1990; Poulsen et al. 1991; Luthje et al. 1996; Hawkins and Fuller 1999; Ostenberg and Roos 2000; Peterson et al. 2000; Hawkins et al. 2001; Woods et al. 2002). Therefore it could be expected that moderate, severe or recurrent injuries could affect players' physical fitness and even the team performance. Some injuries could not only affect performance, but also have health consequences, either immediately or later in life. Studies have shown that knee injuries (especially ACL injuries) usually cause the longest absence from match and training (Ekstrand and Gillquist 1983a; Nielsen and Yde 1989; Luthje et al. 1996; Ostenberg and Roos 2000; Chomiak et al. 2000). Nielsen & Yde (Nielsen and Yde 1989) also found that 28% of players that incurred injuries during the study period, still had complaints one year after the injury occurred.

Drawer and Fuller (Drawer and Fuller 2002b) found from questionnaires from 185 former professional football players, that the players felt that injuries could limit the duration of their playing carrier or result in medical problems, as well as reduce future earning potential. From the same questionnaire they also found that 47% (n=79) of the former professional players retired because of injuries (Drawer and Fuller 2001). Of these, 42% (n=33) were acute injuries (mostly located in the knee, followed by the ankle and low back), but 58% (n=46) were chronic injuries (mainly located in the knee followed by the low back and the hip). They also refer to Windsor Insurance Brokers Limited (1997), which found that 2% of English professional football players retire each year because of an acute injury. Nielsen and Yde (Nielsen and Yde 1989) reported that 4% of players that incurred injuries during one season retired because of their injuries. Ekstrand et al. (Ekstrand et al. 1990) reported that after eight years follow-up of 179 football players, 22% had given up because of injuries. Söderman et al. (Soderman et al. 2002) found that 78% of female football players had stopped playing football 2-7 years after ACL injuries, mostly (80%) because of symptoms from their injured knee.

Roos (Roos 1998) reported that osteoarthrosis was the main chronic injury suffered by former professional football players and this is supported by others (Drawer and Fuller 2001). Studies have shown an increased risk of osteoarthrosis in knees and hips of former elite-level football players, with an odds ratio for the knee of 4.4-5.2 (Roos et al. 1994; Kujala et al. 1995), and 3.7 in the hip compared with an age-matched control group (Lindberg et al. 1993). Furthermore, it has been found that the prevalence of hip and knee osteoarthrosis among former elite football players at an average age of 63 years was 14-15% compared to 3-4% in a control group (Lindberg et al. 1993; Roos et al. 1994). Even when players with a history of previous knee injuries were excluded, 11% of the former elite players still had knee osteoarthrosis compared with 4% in the control group. Compared to the control group, no increase of osteoarthrosis was seen in knees and hips among former players that had played at lower level (Lindberg et al. 1993; Roos et al. 1994). Therefore football at elite level seems to increase the risk of osteoarthrosis.

Injuries in football are also expensive for the players, teams and insurance providers. Dvorak and Junge (Dvorak and Junge 2000) estimated that the medical costs of football associated injuries among around 200 million football players registered with FIFA were around $30 billion per year. This estimate does not include the costs associated with loss of competition or working days. Increased knowledge about risk factors and mechanisms of injuries in football is therefore important, so effective preventive measures can be developed.

Causes of injuries

Risk factors for injuries in sport are commonly divided in intrinsic and extrinsic risk factors. Intrinsic or person-related risk factors can further been classified in physical and psychological risk factors. The physical risk factors consists for example of age, gender, previous injuries, level of play, flexibility, joint instability, generalized joint laxity, muscle strength, aerobic fitness, functional performance, prolonged reaction time, players height, weight and BMI, and anatomical alignment (Taimela et al. 1990a; Inklaar 1994b; Engstrom and Renstrom 1998; Ostenberg and Roos 2000; Dvorak et al. 2000; Gissane et al. 2001). The psychological risk factors reported are for example live-event stress, fighting mentality and risk-taking behavior (Taimela et al. 1990a; Dvorak et al. 2000). Extrinsic or environmental-related risk factors may be the playing surface, player exposure, playing position, time in match, equipment (shin guards, shoes, orthosis, tape), coaching-related factors (quality, training load), rules and foul play (Taimela et al. 1990a; Inklaar 1994b; Engstrom and Renstrom 1998; Gissane et al. 2001).

Football is a complicated sport characterized by short sprints, rapid acceleration or deceleration, turning, jumping, kicking and tackling (Wisloff et al. 1998; Bangsbo and Michalsik 2002). Understanding the etiology of risk factors and mechanisms of injuries in football is an important base of preventive measures. Meeuwisse (Meeuwisse 1994) developed a multifactorial model of athletic injury etiology to examine the contribution of various factors in injury etiology and to explore their interrelationship (Figure. 1). In this model, intrinsic risk factors may predispose an individual to injury, but are seldom sufficient to cause the injury. Then extrinsic risk factors may interact with the intrinsic risk factors, and when both intrinsic and extrinsic risk factors are present the athlete is defined as "susceptible" for injury. However, this is usually not sufficient for injury to occur. The final link in the chain of causation is the inciting event, which is described as all of the events leading to injury. This includes e.g. joint kinematics, the playing situation where the injury took place, the position on the field, the interaction with other players and the skill performed by the injured player (Bahr and Holme 2003). When studying risk factors for injuries, all of these factors must been taken into account, because it is the sum of these factors that causes the injury (Meeuwisse 1994).

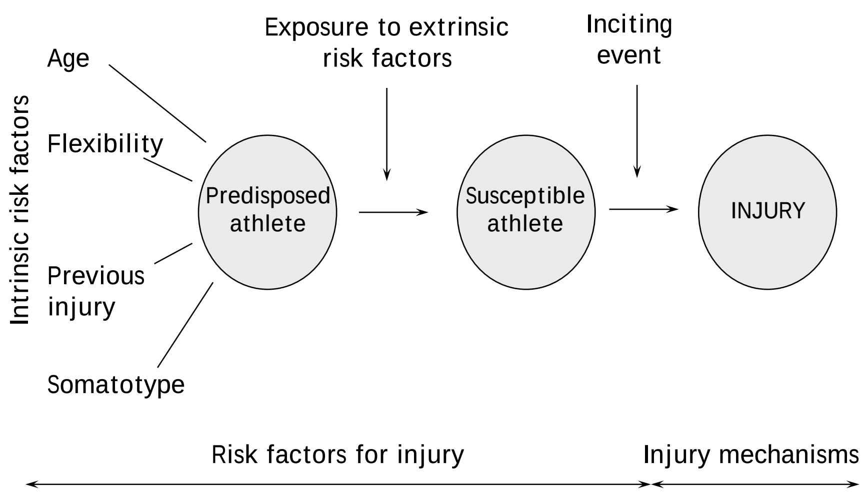

Figure. 1. Multifactorial model of athletic injury etiology (Meeuwisse 1994).

Several studies have examined selected potential intrinsic or extrinsic risk factors (Table 2). Unfortunately, some of these studies have an insufficient number of participants, making the study power too low to obtain significant results. Most of these studies examine the injury frequency in relation to the presence or absence of a single risk factor (univariate analysis). Because of the complexity of risk factor analysis and possible interaction between different risk factors, a multivariate model has been recommended (Meeuwisse 1994; Ostenberg and Roos 2000). However, only two prospective cohort studies were found that have used a multivariate approach to analyze risk factors for injuries in football. They are both recently published but include only relatively few athletes and risk factors (Ostenberg and Roos 2000; Soderman et al. 2001b) (Table 2). In addition, one study used a multivariate model both on retrospective and prospective data (Taimela et al. 1990b), and two retrospective studies used a multivariate approach (Delaney et al. 2001; Delaney et al. 2002). Thus, it should be kept in mind that the research on risk factors for football injuries is limited, both in terms of methodological quality and the number of studies available.

Table 2. Studies on risk factors for injures in football players. Only studies that use statistical methods to test the effect of possible risk factors and include appropriate p-values were included.

Citation **Country**	**Study design**	**Statistic method**	**Study population (age)**	**Duration**	**Injuries studied**	**Factors evaluated as possible risk factors**	**Significant risk factors (p<0.05)**
Delaney et al. (2002) Canada	Retrospective survey	Multivariate logistic regression	82 male and 110 female football players at university level	1 season (1985)	Concussion	Previous concussion during or not during football, previous loss of consciousness during or not during football, years played football, age, age started organized football, participation in other sport, increased alcohol intake, gender, average number of headings per match, amount of season played (summer, fall, winter).	Increased risk of new concussion if previously recognized concussion during football, female sex, participation in other sport.
Delaney et al. (2001) Canada	Retrospective survey	Multivariate logistic regression	70 male and female football players, university level (20.6 ± 2.7)	1 season (1997)	Concussion	Age, number of years plying football, number of matches played during the season, past concussion, past losses of consciousness, alcohol intake.	Increased risk of concussion among players with a history of previous concussion.
Hawkins et al. (2001) England	Prospective cohort	Chi^2 test	2376 male professional football players	2 seasons (1997-1999)	All time loss injuries	Time in match.	Increased risk of injuries during the final 15 min of each half during matches.
Söderman et al. (2001b) Sweden	Prospective cohort	Univariate/ multivariate logistic regression	199 female football players, 2nd and 3rd division (20.6 ± 4.7)	1 season (1998)	Traumatic leg injuries	Age, previous injuries, foot alignment, knee alignment, Q-angle, generalized joint laxity, anterior drawer test for ankle, knee laxity (Lachman, varus, valgus), balance (stabilemetric value), ankle dorsal flexion, hamstring flexibility, H/Q ratio,	Univariate: Increased risk of traumatic leg injuries in players with hyperextension of the knee joint, general joint laxity, low balance (stabilometric value), reduced concentric H/Q ratio. Multivariate: Increased risk of traumatic leg injuries in players with

Citation Country	Study design	Statistic method	Study population (age)	Duration	Injuries studied	Factors evaluated as possible risk factors	Significant risk factors (p<0.05)
Söderman et al. (2001b) continued						exposure.	hyperextension of the knee joint, low balance (stabilometric value), reduced concentric H/Q ratio, higher exposure.
Dvorak et al. (2000) Czech Republic	Prospective cohort	Chi^2-test Student´s t-test	264 football players at different age and skill level	1 year	All time loss injuries	Age, BMI, body fat (%), previous injuries, pain in low back, muscle/tendons or joints, age when beginning football play, started to play football not in a club, technique (self rating), exposure, aching/stiff muscles before match, warm-up, 12 min run, reaction time, drinking alcohol, more a "fighter" when getting near an opponent, life-event stress, change of coach, transfer to another club.	Injured players had lower body fat (%), higher score of pain in joints, more often started to play football not in a club, less training exposure during the preseason period and the season, lower score of technique (self rating), longer reaction time after 12 min runs, more players drinking alcohol at least once a week, more a "fighter" when getting near an opponent.
Östenberg and Roos (2000) Sweden	Prospective cohort	Univariate/ multivariate logistic regression	123 female football players at different age and skill levels (14-39 y)	1 season (1996)	All time loss injuries	Age, weight, height, BMI, years of playing football, Generalized joint laxity, Isokinetic hamstring and quadriceps muscle strength, estimated VO_{2max} (continous multistage fitness test), one leg hop, vertical jump, square-hop.	Univariate: Increased risk of injuries if football career is longer, increased generalized joint laxity, and increased knee hypermobility. Multivariate: Increased risk of injuries if age ≥ 25 years, number of square-hop ≥ 25 per 30 seconds, generalized joint laxity both for all injuries and for knee injuries separately.
Hawkins and Fuller (1999) England	Prospective cohort	Chi^2-test	108 professional and 30 youth football players	3 seasons (1994-1997)	All time loss injures	Time in match.	Increased risk of injuries during the final 15 min of first half and final 30 min of second half. More injuries during second half than first half.

Citation Country	Study design	Statistic method	Study population (age)	Duration	Injuries studied	Factors evaluated as possible risk factors	Significant risk factors ($p<0.05$)
Bjordal et al. (1997) Norway	Retrospective questionnaire	Chi^2 test	176 male and female football players at various level (15-55 y)	(1982-1991)	ACL	Gender, age, level of play.	Gender: Incidence of ACL injures higher among females than males. Level of play: Incidence of ACL injuries among males higher at higher level of play.
Inklaar et al. (1996) Netherlands	Prospective cohort	Insufficient information on statistic methods	245 senior and 232 junior male non professional football players (21.6 ± 8.4, range 13-60 y)	2nd half of the 1996/1997 season (Feb.-June)	All (not only time loss)	Age, level of play, previous injuries.	Increased injury incidence rate at higher level of play, and at the age of 17-18 years.
Arendt and Dick (1995) USA	Retrospective data collected from NCAA injury Surveillance System	Chi^2 test	On the average 92 collage male teams and 56 college female teams per year	5 years (1989-1993)	Knee injuries	Gender.	Females have higher rate of ACL injuries and cartilage injures (including meniscus) than males.
Roos et al. (1995) Sweden	Retrospective questionnaire based on data from insurance company	Chi^2-test	778 male and female football players at various level	One year (1986)	Knee injuries	Age, gender, level of play, playing position.	Increased risk of ACL injuries in: females compared to males, females had higher risk of sustaining ACL injury at younger age than males, elite players, players in forward position.
Lindenfeld et al. (1994) USA	Prospective cohort	Chi^2-test	Male and female football players at various age and level of play (7-50 y)	7 weeks (300 indoor games at local indoor football arena)	All, if player left match, or requested medical attention, or match stopped because of injury	Age, gender.	Age: Increased injury rate in males aged ≥ 25 years. Gender: Higher rate of ankle sprains among males, but knee sprains among females.

Citation Country	Study design	Statistic method	Study population (age)	Duration	Injuries studied	Factors evaluated as possible risk factors	Significant risk factors ($p<0.05$)
Poulsen et al. (1991) Denmark	Prospective cohort	Chi^2-test with stratification using Mantel-Haenszel method	19 elite football players (21-28y) and 36 players at lower level (24-30 y)	1 year	All time loss injuries	Level of play.	No difference in injury incidence in different levels of play when stratified for match and training.
Taimela et al. (1990b) Finland	Retrospective and prospective	Stepwise regression analysis	37 male football players at various level of play	3 years before test, 1 year after test	All time loss injuries	Previous injuries, reaction time, arm-hand-steadiness, balance, speed of arm and leg movements, multilimb coordination, vertical jump, figure-8-running, personality factors.	Correlation was found between previous injuries and long reaction time, as well as personality factors (high score for astute, low score for shy). No correlation between injuries during the follow-up period and motor abilities or personality factors.
Backous et al. (1988) USA	Prospective collected	Chi^2-test	681 boys and 458 girls at summer soccer camp (6-17 y)	4½ days of activity	All time loss injuries	Girls: Age. Boys: Age, weight, height and, grip strength.	Double injury incidence after age of 14 (boys and girls), significantly higher injury rate among tall and weak boys.
Eriksson et al. (1986) Sweden	Prospective cohort	Fishers exact test	40 male football players form 4th division (23.6 ± 4.0)	1 year (1980)	Time loss injuries classified as: overuse, sprains and other	Estimated maximal O_2 uptake on ergometer bicycle.	The group of players with the highest estimated maximal O_2 uptake incurred significantly more overuse injuries.
Tropp et al. (1984) Sweden	Prospective cohort	Chi^2-test	127 male football players (17-38 y)	1 season (1980)	All time loss injuries especially ankle injuries	Previous ankle injuries, stabilometry.	Increased risk of ankle injuries among players with pathologic stabilometry.

Citation Country	Study design	Statistic method	Study population (age)	Duration	Injuries studied	Factors evaluated as possible risk factors	Significant risk factors ($p<0.05$)
Ekstrand and Gillquist (1983b) Sweden	Prospective cohort	Insufficient information on statistical methods	180 male football players in 4th division (24.6 ± 4.6, range 17-38 y)	1 year (1980)	All time loss injuries	Previous injuries, joint instability, muscle tightness in hip adductors, hip flexors, hamstring, quadriceps and gastrocnemius, hamstring and quadriceps isokinetic strength, H/Q ratio, lack of training, inadequate rehabilitation, inadequate use of shinguards, quality of playing surface.	Increased risk of ankle sprains in players with a history of previous sprain or clinical instability of the ankle. Increased risk of non-contact knee injuries in players with a history of previous knee sprain and persistent instability, and in players with reduced knee-extension strength. Players that incurred adductor rupture or tendinitis, had lower ROM in hip abduction than the other players.
Ekstrand et al. (1983b) Sweden	Prospective cohort	Insufficient information on statistical methods	180 male football players from 4th division (24.6 ± 4.6, range 17-38 y)	1 year (1980)	All time loss injuries	Player exposure in match and training.	Teams with more or less than average training had decreased frequency of traumatic injuries compared to the intermediate group.
Ekstrand and Gillquist (1983a) Sweden	Prospective cohort	Chi²-test Student t-test, Fischer´s exact test	180 male football players from 4th division (24.6 ± 4.6, range 17-38 y)	1 year (1980)	All time loss injuries	Previous injuries, time of injuries during in matches and training.	Increased risk of ankle sprains in players with a history of previous ankle sprain. Increased risk of muscle strains during warm up and the beginning of matches. Increased risk of knee sprains during the end of training sessions.

Intrinsic risk factors

Age

In several studies age have been investigated as a possible risk factor for injuries in football (Backous et al. 1988; Lindenfeld et al. 1994; Roos et al. 1995; Inklaar et al. 1996; Bjordal et al. 1997; Ostenberg and Roos 2000; Dvorak et al. 2000; Delaney et al. 2001; Soderman et al. 2001b; Delaney et al. 2002). Studies have shown that injury incidence in adolescent or junior players increases with age (Hoff and Martin 1986; Schmidt-Olsen et al. 1991; Inklaar et al. 1996), and Backous et al. (Backous et al. 1988) found that injury risk doubled after the age of 14 in youth football players (6-17 years) participating in a summer football camp. The oldest high-level junior players (17-18 years) usually have similar or slightly higher injury incidence rates than high level adult players (Inklaar et al. 1996; Hawkins and Fuller 1999). Only Östenberg and Roos (Ostenberg and Roos 2000) used a multivariate analysis to compare age and some other potential risk factors for injuries and found that female players older than 25 years were at significantly higher risk of injuries than younger players. This was confirmed in one study on male football players using univariate analysis (Lindenfeld et al. 1994), but other studies found no such difference (Dvorak et al. 2000; Soderman et al. 2001b). Studies also indicate that the number of years in active football play could be associated with new injuries (Ostenberg and Roos 2000; Dvorak et al. 2000). This factor can be related to player age and previous injures, and disappeared when corrected for age in a multivariate analysis by Östenberg and Roos (Ostenberg and Roos 2000).

Gender

Östenberg and Roos (Ostenberg and Roos 2000) stated that the general injury rates for Swedish male and female football players were similar, but knee injuries were more common in female football players. Lindenfeld et al (Lindenfeld et al. 1994) also found a similar overall injury rate for male and female players in indoor football, but males had an increased risk of sustaining ankle ligament injuries, while females had an increased risk of sustaining knee ligament injuries. Arendt and Dick (Arendt and Dick 1995) found that knee injuries were more common in females than males among college football players in the US, and

ACL injury rate (injuries/1000 athletic-exposures) in females were more than double that of males. This was true both for practice and games. The rate of torn cartilage, including meniscus tears, and collateral ligament injuries were also significantly higher in female than in male players. Roos et al. (Roos et al. 1995) found that ACL injuries occurred at a younger age in females (average 19 years) than in male players (average 23 years), and Bjordal et al. (Bjordal et al. 1997) estimated that the risk for ACL injuries among junior football players was 5.4 times higher for girls than for boys. Many factors can contribute to this difference, both training-related factors such as less muscle strength or lack of muscle control and anatomical factors such as wider pelvis, more valgus in knees and increased joint laxity among female players (Ostenberg and Roos 2000). A prospective study on female football players indicate that they were more susceptible to traumatic injuries during the premenstrual and menstrual period compared to the rest of the menstrual cycle (Moller-Nielsen and Hammar 1989). Another study on female team handball players also indicates that there is an increased risk of ACL injuries during the week prior to or after the start of the menstrual period (Myklebust et al. 1998).

Previous injuries

Many studies have investigated previous injuries as a possible risk factor for injuries in football (Ekstrand and Gillquist 1983a; Ekstrand and Gillquist 1983b; Tropp et al. 1984; Taimela et al. 1990b; Inklaar et al. 1996; Dvorak et al. 2000; Delaney et al. 2001; Soderman et al. 2001b; Delaney et al. 2002). Ekstrand and Gillquist (Ekstrand and Gillquist 1983a; Ekstrand and Gillquist 1983b) found an increased risk of ankle and knee sprains in players with a history of previous sprains or clinical instability in ankles and knees. Delaney et al. (Delaney et al. 2000; Delaney et al. 2001; Delaney et al. 2002) found in retrospective studies that football players had increased risk of incurring a concussion if they had a previously recognized concussion during football. Studies indicate that recurrent injuries represent 22-42% of total number of injuries in football (Ekstrand et al. 1983a; Nielsen and Yde 1989; Hawkins and Fuller 1999; Chomiak et al. 2000). Recurrent muscle strains account for 26-61% of all strains (Nielsen and Yde 1989; Inklaar 1994b; Hawkins and Fuller 1999), and recurrent ligament sprains for 30% of all sprains (Hawkins and Fuller 1999). Studies have also shown that recurrent ankle sprains represent 32-56% of all ankle sprains occurring in football (Ekstrand and Gillquist 1983a; Nielsen and Yde 1989; Hawkins and Fuller 1999).

However, Tropp et al. (Tropp et al. 1984) found no correlation between previous ankle sprains and new sprains in football players. Ekstrand and Gillquist (Ekstrand and Gillquist 1983a) also indicated that even minor injuries could predispose for more severe injuries of same or other type and location (Ekstrand and Gillquist 1983a).

Joint instability

Joint instability can be classified as mechanical or functional instability. Mechanical instability is when ligaments or even the joint capsule are elongated and non-physiologic movements are possible in the joint. Functional instability is defined as recurrent sprains or feeling of giving way (Tropp et al. 1985b). Stabilometry is commonly used to assess functional instability (Tropp et al. 1984).

Mechanical instability in ankles and knee have been studied as a possible risk factor for football injures (Ekstrand and Gillquist 1983b; Soderman et al. 2001b). Such instability can be a consequence of previous ligament sprains, stretching of ligaments and joint capsule or generalized joint laxity. Studies on football players have shown that there is an increased rate of mechanical instability in ankles and knees after previous sprains (Ekstrand et al. 1983b; Brynhildsen et al. 1990). A study on football, lacrosse and field hockey players showed that ankle sprains are more frequent in players with mechanical instability (increased talar tilt) in their ankles (Beynnon et al. 2001). However, other studies found no such relationship among football, field hockey, lacrosse and basketball players (Barrett et al. 1993; Baumhauer et al. 1995). Ekstrand and Gillquist (Ekstrand and Gillquist 1983a) found that 14% of football players in their study had persistent knee instability resulting from past injury. Chomiak et al. (Chomiak et al. 2000) found that 39% of non-contact knee injuries incurred in mechanical unstable knees (as assessed by Lachmann test, valgus and varus stress tests).

Several studies have investigated functional instability as a possible risk factor for injuries in football players (Tropp et al. 1984; Taimela et al. 1990b; Soderman et al. 2001b). Studies have shown that players with clinically diagnosed functional instability (recurrent sprain or feeling of giving way) have a higher stabilometric value when balancing on force plate than players without functional instability (Tropp et al. 1985b; Tropp 1986). Tropp et al. (Tropp et al. 1984) have also found that players with an increased stabilometric value had a significantly higher rate of ankle sprains during the following season than other players, which is in accordance with studies on basketball players (McGuine et al. 2000). Functional instability in ankles have also been found to be associated with pronator muscle weakness (Tropp 1986), and Konradsen et al. (Konradsen et al. 1998) found a decrease in peroneal eccentric strength 3 weeks after injury compared to the non-injured leg. Konradsen and Ravn (Konradsen and Ravn 1991) found that the reaction time of peroneal muscles was longer in functionally unstable ankles than in functionally stable ankles, but in another study, they found no difference in peroneal reaction time 3, 6 and 12 weeks after an ankle inversion injury (Konradsen et al. 1998). A clear correlation between mechanical and functional instability has not been found, and Tropp et al. (Tropp et al. 1985b) found that the stabilometric value did not differ between mechanically stable and unstable ankles.

Generalized joint laxity (Baumhauer et al. 1995) has been considered as a possible risk factor for injuries in football. Östenberg and Roos (Ostenberg and Roos 2000) found increased risk of all injuries and knee injuries separate in female players with generalized joint laxity. Söderman et al. (Soderman et al. 2001b) also found an increased risk of traumatic leg injuries in female players with generalized joint laxity. However, studies on football, lacrosse and field hockey players did not show any association between generalized joint laxity and ankle sprains (Baumhauer et al. 1995; Beynnon et al. 2001).

Flexibility

One study showed that football players were less flexible in hip adductors, hip flexors, knee flexors and ankle dorsal flexors than a control group that did not play football (Ekstrand and Gillquist 1982). The reason for this can be the characteristics of the sport, which is characterized by high intensity, including short sprints with sudden turns as well as increase or decrease of speed. This puts a high demand on the muscles. Moreover, insufficient attention is often paid to flexibility training in football (Hawkins and Fuller 1998a). Although many believe that muscle tightness is an important risk factor for muscle strains in football, few studies are available that confirm such relationship. However, Ekstrand and Gillquist (Ekstrand and Gillquist 1983b) found that players with less flexible hip adductors sustained significantly more adductor muscle ruptures or overuse injuries than players with more flexibility, but other studies have not confirmed this finding, or found any association between flexibility and injuries in football players (Watson 2001; Soderman et al. 2001b).

Therefore, there is a lack of evidence to decide whether muscle tightness could be a risk factor for muscle strains in football. Results from studies on other types of sports are equivocal and difficult to compare because of different methods in measuring flexibility. Some of these studies show no correlation between injuries and flexibility or flexibility imbalance between right and left (Hennessey and Watson 1993), while other indicate some correlation (Knapik et al. 1991; Jonhagen et al. 1994; Krivickas and Feinberg 1996).

Muscle strength and strength ratio

Many authors have discussed the importance of strength as a possible risk factor for injuries in football (Ekstrand and Gillquist 1983b; Inklaar 1994b; Baumhauer et al. 1995; Ostenberg et al. 1998; Engstrom and Renstrom 1998; Ostenberg and Roos 2000; Dvorak and Junge 2000; Soderman et al. 2001b). However, relatively few studies have been performed on football players (Ekstrand and Gillquist 1983b; Ostenberg and Roos 2000; Soderman et al. 2001b). Ekstrand and Gillquist (Ekstrand and Gillquist 1983b) found that players that incurred non-contact knee injuries had significantly lower knee-extension strength in the injured leg compared to uninjured players, but they did not take into account possible confounding factors like strength reduction as result of previous knee injuries. Baumhauer et al. (Baumhauer et al. 1995) studied football, lacrosse and field hockey players and found that preseason eversion-to-inversion strength ratio in ankles was significantly lower in the group of players that incurred ankle sprains during the subsequent season than in other players. Yamamoto (Yamamoto 1993) found with isometric strength tests in track and fields athletes that less hamstring strength per body weight and hamstring-to-quadriceps strength ratio were associated with increased risk of hamstring strains. Results from Australian rules football show that preseason hamstring muscle weakness measured isokinetically at 60°/s was associated with hamstring muscle injury in the following season (Orchard et al. 1997). These results were not confirmed by another study from Australian rules football (Bennell et al. 1998), or a study on female football players (Ostenberg and Roos 2000). However, Söderman et al. (Soderman et al. 2001b) found that decreased concentric hamstring-quadriceps strength ratio among female football players was a significant risk factor for traumatic leg injuries and increased hamstring-quadriceps strength ratio was related to a higher risk of overuse injuries. Nevertheless, it is reasonable to believe that playing and training football can result in imbalances in the strength ratio between the hamstrings and quadriceps. This is because football training and playing would be expected to increase the strength of the quadriceps more than the hamstring, for example as a result of kicking the ball, sudden acceleration or deceleration and turning. Strength training in football has commonly also focused more on the quadriceps muscles than the hamstrings, and most strength exercises that have frequently been used have much stronger concentric phase than eccentric phase. Therefore it is reasonable to believe that the hamstring-quadriceps strength ratio can be reduced in football players, and especially the eccentric strength of the hamstrings.

Aerobic fitness

It is commonly considered that high aerobic fitness contributes to increased player performance and higher intensity of play (Bangsbo and Lindquist 1992; Di, V and Pigozzi 1998; Wisloff et al. 1998; Helgerud et al. 2001). It has also been discussed whether low aerobic fitness could contribute to increased fatigue late in games (Wisloff et al. 1998) and possibly increase risk of injuries because of reduction in the protective effects of the muscles and altered distribution of forces acting on the muscles, ligaments, cartilage and bones (Eriksson et al. 1986; Jones et al. 1993; Bell et al. 2000; Knapik et al. 2001; Murphy et al. 2003). Although numerous studies have tested the maximal O_2 uptake among football players (Rhodes et al. 1986; Bangsbo et al. 1991; Bangsbo and Lindquist 1992; Helgerud et al. 2001), no one has assessed the relationship with injury risk. However, two studies on injuries in football estimates maximal O_2 uptake from submaximal tests. Östenberg and Roos (Ostenberg and Roos 2000) found no differences in the estimated maximal O_2 uptake between injured and non-injured groups of female football players, using a multistage fitness test. Eriksson et al. (Eriksson et al. 1986) found significantly higher incidence of overuse injuries in football players with higher estimated maximal O_2 uptake (tested on a bicycle ergometer) compared to players with lower estimated maximal O_2 uptake. Dvorak et al. (Dvorak et al. 2000) found that players that incurred injuries during one season, had significantly longer recovery time after 12 min run in preseason tests than uninjured players. Because none of these studies have used direct methods to measure maximal O_2 uptake, we do not know what the effect of aerobic fitness is on the risk of injuries in football.

Functional performance

Many different tests have been used to study functional performance in football players (Rosch et al. 2000), but reports on the relationship between such factors and injury rate are scarce. However, Östenberg and Roos (Ostenberg and Roos 2000) found in a multivariate analysis that players who performed more than 25 square jumps per 30 seconds preseason incurred significantly more injuries compared to those who performed fewer. Taimela et al. (Taimela et al. 1990b) also found a correlation between previous injuries and slow reaction time for light stimulus. On the contrary Junge et al. (Junge et al. 2000b) found no such correlation. Further research is needed to indicate whether some functional tests could be a predictor for injuries in football.

Level of play

Some studies have found higher incidence of injuries among players at higher than lower level of play, both for injuries in general (Nielsen and Yde 1989; Inklaar et al. 1996), and ACL injuries in particular (Roos et al. 1995; Bjordal et al. 1997). This can be related to higher playing intensity, more exposure time during training and match and a higher training load by high level players (Ekstrand and Tropp 1990; Inklaar et al. 1996). Ekstrand and Tropp (Ekstrand and Tropp 1990) found a trend towards a higher incidence of injuries in matches among the higher division teams, but a lower incidence during training. No difference was found in the incidence of ankle sprains between divisions. Poulsen et al. (Poulsen et al. 1991) found no difference in injury incidence between players at different level of play. Peterson et al. (Peterson et al. 2000) found that players at a low level of play had two to three times higher incidence of injuries than high level players in the same age group. Similarly, Chomiak et al. (Chomiak et al. 2000) reported a twofold higher incidence of severe injuries in a group of players at lower level of play compared to a group of players at a higher level of play. This can be due to inadequate physical performance among players at lower level of play, less time spent in training, insufficient player technique or team tactic, inadequate training conditions, as well as psychological factors (Ekstrand and Tropp 1990; Poulsen et al. 1991; Peterson et al. 2000). These studies seem to be contradictory. However, severe knee injuries seem to be more frequent among high level players, but it is difficult to conclude about the effect of the level of play on general injury incidence.

Other factors

Few other factors have been studied as possible intrinsic physical risk factors for injuries in football. No difference has been found between injured and uninjured football players in height or weight (Baumhauer et al. 1995; Ostenberg and Roos 2000; Beynnon et al. 2001), except in one study of adolescents where tall and muscularly week boys incurred significantly more injuries than short and week or tall and strong boys (Backous et al. 1988). Body mass index has been compared between injured and uninjured group of female players without statistical difference (Ostenberg and Roos 2000).

Few studies are found that examine the relationship between anatomical alignment and injuries, but Söderman et al. (Soderman et al. 2001b) found in univariate analysis, that hyperextended knees in female football players was related to a higher risk of traumatic lower leg injures. Beynnon et al. (Beynnon et al. 2001) also found an association between tibial varum among female football players and an increased risk of ankle ligament injuries.

Psychological characteristics

Participation in sport requires not only physical skills but also psychological skills and preparation. Andersen and Williams (Andersen and Williams 1988) developed a model of stress and athletic injury. They argued that the reaction to a potentially stressful situation could predict injury. In another paper, they also found that negative life event stress was a significant predictor of injuries in athletes (Andersen and Williams 1999). Although many psychological studies have been performed on athletes, I was just able to find three studies that deal with psychological factors as possible risk factors for injuries in football (Taimela et al. 1990b; Dvorak et al. 2000; Junge et al. 2000b).

Dvorak et al. (Dvorak et al. 2000) found that injured players scored significantly higher in a questionnaire about life-event stress than uninjured players, which is in accordance with studies from American football as reported by Junge (Junge 2000) and athletes from other sports (Andersen and Williams 1999). They also found that compared to uninjured football players, injured players at different level of play, more often described themselves as a "fighter" when getting past an opponent. Studies have also found that football players had greater chance of suffering a concussion during one season if they had sustained a previous concussion while playing football (Delaney et al. 2001; Delaney et al. 2002), which can indicate risk-taking behavior. Taimela et al. (Taimela et al. 1990b) studied football players at different ages and level of play. They found a correlation between two personality factors (high score in astute and low score in shy) and previous injuries. No factors were found that correlated with injuries during the following season. Junge et al. (Junge et al. 2000b) found that players with a history of seven or more previous injuries had significantly more worries about their performance, more competitive anxiety, more peaking under pressure, a higher anger trait, and increased outward anger expression. These studies indicate that psychological factors such as life-event stress, fighting mentality and risk taking behaviour can possibly predispose to injuries in football.

Summary of intrinsic risk factors

Studies on adolescents have shown that injury risk increases with age up to 17-18 years, where injury incidence is similar as for adult players. Some studies on adult players also show an increased risk of injuries with increasing age, while other fail to show such a trend. The overall injury rate seems to be similar between male and female football players, but knee injuries in particular are more frequent in female players. Previous injures have been shown to increase the risk of new injuries of the same type and location, especially for ankle and knee sprains, as well as for concussion. Recurrent muscle strains are also common. Some studies report a higher incidence of ankle sprains for mechanically or functionally unstable ankles, while others do not. Just one study on football players has indicated a possible relationship between short muscles (adductors) and injuries, while other studies show no such correlation. One study on female football players found that a decreased concentric hamstring/quadriceps strength ratio was associated with traumatic leg injuries. Studies from other sports indicate that a low hamstring/quadriceps strength ratio could increase the risk of hamstring strains. Although numerous studies have tested the maximal O_2 uptake among football players, the relationship with injuries has not been studied. Some studies indicate a higher injury incidence among players at higher level of play, while other studies have shown the opposite. No difference has been found between injured and uninjured groups of players in height, weight or body mass index. Little information is available on the possible effects of anatomical alignment or reaction time on injury incidence in football players. Studies have indicated that psychological factors such as life-event stress, fighting mentality and risk taking behavior could possibly predispose to injuries. Most studies have used univariate analysis, which compares one variable at the time between injured and uninjured groups of players, and does not take into account potential confounding effects of other variables. The conclusion is that results from previous studies are contradictory and relatively little is known about which physical or psychological characteristics could be considered as risk factors for injuries. More large studies are needed taking a multivariate approach, to examine potential intrinsic risk factors for injuries and their interrelationship.

Extrinsic risk factors

Training load, intensity and coaching

Training load has been discussed as a possible risk factor for injuries in football. Injury incidence is higher during matches than during training, which probably reflects the increased load, intensity and more aggressive playing style. Few studies have examined training load as a potential risk factor for injuries in football. However, Ekstrand et al. (Ekstrand et al. 1983b) found a significant nonlinear relationship, where teams with an average training volume incurred more acute injures than teams with less or more training. No such difference was found in overuse injuries. Dvorak et al. (Dvorak et al. 2000) also found that injured players had trained less than uninjured players. Studies have also shown a relationship between a high training to match ratio and a lower incidence of injuries (Ekstrand et al. 1983b). This indicates that a sufficient training load may be important to prevent injuries.

The quality of coaching has also been discussed as a possible risk factor for injuries (Ekstrand et al. 1983b). Coaches' education and experience, and how they cooperate with the medical team if it is available, could also be important factors. Ekstrand et al. (Ekstrand et al. 1983a) found significant reduction of injuries, with use of a multifactoriael prevention program. One element in this program was correction and supervision of training. However, it is unclear which of the elements in the program was effective in the prevention of injuries. Previously, inadequate warm-up or shooting at goal before warm-up was common in football. Ekstrand et al. (Ekstrand et al. 1983b) found that all of the quadriceps muscle strains that occurred in their study affected players in teams that allowed shooting at the goal before warming-up. Dvorak et al. (Dvorak et al. 2000) found that warm-up was more often inadequately or incompletely performed among severely injured football players than uninjured players. This indicates that too little is known about the effect of coaching factors on injury risk in football.

Playing position and location on the field

Few studies are available on injury risk in football related to player position or location on the field. Hawkins and Fuller (Hawkins and Fuller 1996) found that defenders had higher injury risk than midfielders. Boden et al. (Boden et al. 1998) found that most concussions among male football players occurred in forward and midfield players, but among female players most concussions occurred among defensive players. Other studies have not found differences in injury rate between different playing positions (Ekstrand and Gillquist 1983a; Nielsen and Yde 1989; Luthje et al. 1996; Hawkins and Fuller 1998b; Chomiak et al. 2000). Chomiak et al. (Chomiak et al. 2000) found that 33% of injuries occurred on the own half, 21% close to the midline and 46% on the opponent half. Rahnama et al. (Rahnama et al. 2002) found that 30% of injuries occurred in the defending area, 40% in the midfield area and 30% in the attacking area (all areas were of the same size). Therefore, most studies have not found any difference in injury risk between different playing positions, but more research is needed that take into account different playing strategy of the participating teams.

Time in match

Several authors have studied when during a match or training session injuries occur. Östenberg & Roos (Ostenberg and Roos 2000) found that 60% of the injuries in their study occurred after 60 minutes of play or practice or later. Moderate and major injuries also occurred later than minor injuries. Other studies have found an increase in the number of injuries during the final 15 minutes of the first half and the final 30 minutes of the second half for both professional and youth players (Hawkins and Fuller 1999; Hawkins et al. 2001). They also found that more injuries occurred in the second half compared with the first half for both professional and youth players. In contrast, Ekstrand and Gillquist (Ekstrand and Gillquist 1983a) reported that most muscle strains occurred during warm-up and at the beginning of the match, indicating insufficient warm-up before shooting, passing and sprinting, while ligament sprains were evenly distributed throughout the match. Chomiak et al. (Chomiak et al. 2000) found no difference in the distribution of injuries between the first and second halves of the games. Boden et al. (Boden et al. 1998) found that head injuries occurred on the average in the 72nd minute in male matches and in the 63rd minute in female matches. Most of these studies indicate an increased risk of injuries during the second half or the last part of each half, which may reflect a fatigue effect (Hawkins and Fuller 1999; Hawkins et al. 2001).

Field condition (playing surface, weather condition)

Football is usually played on natural grass, but during the last fifteen to twenty years the use of artificial turf has increased, while use of gravel fields has decreased. The quality of artificial turf has improved through the years, with attention on optimal hardness (the ability to absorb impact energy) and shoe-surface friction (the footing or grip provided between surface and shoe), which are the two main surface-related risk factors documented (Ekstrand and Nigg 1989; Inklaar 1994b; Milburn and Barry 1998; Orchard 2002). To allow high-intensity movements in football such as sprinting, rapid acceleration and deceleration, cutting, pivoting and gliding for example in tackling, the translational (sliding) and rotational friction between shoe and surface must be suitable. If the translational or rotational friction is too high, the players can run a higher risk of injuries such as ligament sprains in ankle and knee or even fractures because the high friction does not allow sufficient movement between the surface and the shoe. If the friction is too low, it can decrease the players maximal speed and their ability to accelerate and decelerate or turn quickly, and the players can slip and even fall when it is not wanted (Ekstrand and Nigg 1989). Under such circumstances injuries such as groin strains can easily occur. Hard surfaces increase impact forces and can possibly results in overload of tissues because of a large single impact or repeated submaximal impact forces (Ekstrand and Nigg 1989; Inklaar 1994b). Studies from Australian rules football indicate that playing on harder surface will increase match speed, which again can increase the risk of injuries (Norton et al. 2001; Orchard 2002).

Although many authors propose that high shoe-surface friction and increased hardness of the playing ground increase the injury risk, no study is available where friction of natural grass and artificial turf has been measured and compared to injury rate in football (Orchard 2002). However, Orchard (Orchard 2001) measured ground hardness of natural grass fields before matches in the Australian Football League and found a non-significant trend to a higher risk of ACL injuries on harder fields.

Many confounders are possible in studies of shoe-surface friction and hardness of surface as possible risk factors for injuries. A wet or dry surface, the amount of rainfall and evaporation, temperature, length of cleats, material and structure of the shoe surface, intensity of the play, running speed, level of play, etc. can easily affect results if they are not controlled (Orchard 2002). Also, different kinds of artificial turf are available with somewhat different friction and hardness. The type of natural grass and soil moisture can also vary, resulting in different shoe-surface friction and ground hardness as reported by Orchard (Orchard 2002). Therefore, an exact comparison between artificial turf and natural grass is difficult.

However, several studies have been performed in different sports to investigate injury risk with playing on different surfaces. Two studies report higher injury rate on artificial turf than on natural grass (Stevenson and Anderson 1981; Powell 1987) and this is supported by a resent study (Hagel et al. 2003). Nigg and Segesser (Nigg and Segesser 1988) also reported in their review article some studies that found no differences in injury rate between natural grass and artificial turf or even lower injury rate on artificial turf. Studies are found that indicate different injury profile on different surface types. In American football, foot and ankle injuries have been reported to be more common on artificial turf than on natural grass (Powell 1987), and similar results are shown for knee injuries (Powell 1987; Powell and Schootman 1992). Scranton et al. (Scranton, Jr. et al. 1997) found a higher rate of non-contact ACL injuries on natural grass during match, but on artificial turf during training. In a study from Australian rules football a low water evaporation and high rainfall, which indicate a softer surface with lower shoe-surface friction, decreased the risk of non-contact ACL injuries (Orchard et al. 1999; Orchard et al. 2001). There is also strong evidence that there is a higher injury risk in the dry season in rugby league and Australian rules football, which can indicate the effect of increased hardness and friction (Orchard 2002). A study from American football found that shoes with higher torsional resistance (longer cleats placed at the peripheral margin of the sole and a number of smaller cleats positioned interiorly), were related to an increased number of ACL injuries (Lambson et al. 1996). In addition, authors have argued that frequent changes between different surfaces could predispose to increased risk of overuse injuries (Ekstrand and Gillquist 1983b).

Most studies seem to indicate that a high shoe-surface friction and ground hardness increase injury risk, and more injuries occur on artificial turf than on natural grass, especially knee and ankle injuries. However, there are a number of potential confounding factors, mostly related to shoe-surface friction and ground hardness, which make the interpretation of the data difficult.

Equipment (shin guards and footwear)

Adequate shin guards are assumed to be important in football. Ekstrand and Gillquist (Ekstrand and Gillquist 1983b) found that all traumatic leg injuries that occurred in their study affected players using inadequate or no shin guards, and Backous et al. (Backous et al. 1988) reported a lower number of lower leg injuries among adolescents using shin guards. Studies have also reported that the protective effect of shin guards is different between types of shin guards and their material (Bir et al. 1995; Francisco et al. 2000).

Football shoes are usually tight fitting and provide little protection, support and cushioning. Some authors have suspected the shoes to increase the risk of some overuse injuries (Inklaar 1994b). The length of cleats can also be important in relation to shoe-surface friction. Furthermore, a contract with one shoe producer is common among elite teams, so all of the players in the team must play in shoes from the same producer without regard to their foot shape.

Rules and foul play

Injuries that occur in contact with another player are common in football. Most of these situations occur when two or more players try to win the ball at the same time, or a player attempts to win the ball from an opponent. Studies on the influence of foul play on injury rate are equivocal. In some of these studies foul play called by the referee are studied (Ekstrand et al. 1983b; Engstrom et al. 1990; Hawkins and Fuller 1996; Hawkins and Fuller 1998b; Hawkins and Fuller 1999), while in other studies players reported whether it was foul or not (Nielsen and Yde 1989; Luthje et al. 1996; Chomiak et al. 2000; Peterson et al. 2000;

Junge et al. 2000a). Results have shown that foul play was the cause of 16-28% of all injuries (Nielsen and Yde 1989; Hawkins and Fuller 1996; Hawkins and Fuller 1999; Peterson et al. 2000; Junge et al. 2000a), or 28-30% of traumatic injuries (Ekstrand and Gillquist 1983b; Engstrom et al. 1990). Other studies have found that 76-86% of the foul play injuries were caused by opponent and the rest by own foul (Ekstrand and Gillquist 1983b; Hawkins and Fuller 1999), and also that own foul play resulted in more serious injuries than opponent foul (Ekstrand and Gillquist 1983b). In contrast, Chomiak et al. (Chomiak et al. 2000) reported no serious injuries in players after own foul.

Summary of extrinsic risk factors

Studies have indicated that a low volume of training, a low training to match ratio and inadequate warm-up could be risk factors for injuries in football. Some studies report a higher incidence of injuries during the second half or the last part of each half, indicating possible fatigue effect, while other studies have found no such trend. Most studies have shown a higher injury rate on artificial turf than on natural grass, especially for knee and ankle injuries. It is assumed that this difference can reflect a higher shoe-surface friction and ground hardness on artificial turf. High rainfall and low water evaporation, resulting in lower shoe-surface friction and a softer surface, have also been shown to decrease the risk of ACL injuries in Australian rule football. The type of cleats used has been shown to affect the shoe-surface friction and is thought to be of importance. Use of inadequate or no shin guards increases the risk of traumatic lower leg injuries. Studies have also reported that 28-30% of traumatic injuries occurred during foul play. In conclusion, there is a lack of information on extrinsic risk factors for injuries in football. Therefore, more research is needed to study the effect of extrinsic risk factors and their relation to intrinsic risk factors, as well as injury mechanisms.

Injury mechanisms

Understanding the injury mechanisms in football is of prime importance when considering preventive measures. Today, limited information is available on injury mechanisms in football. Most studies only classify injuries as contact and non-contact mechanisms (Arendt and Dick 1995; Ostenberg and Roos 2000; Heidt, Jr. et al. 2000; Chomiak et al. 2000), but studies are also found that are more specific (Yde and Nielsen 1990; Hawkins and Fuller 1999; Hawkins et al. 2001). Although most of these studies are prospective and injury mechanisms are registered by team doctors, physical therapists or athletic trainers, it is difficult to analyze injury mechanisms from the sideline. They only see the injury once and just from one side, making it impossible to analyze in details the mechanism and the playing situation. Questionnaires answered by players also give limited information because of recall bias. Injuries happen quickly and the players may not remember in detail the playing situation or the moment of injury. Previously, video-based match analysis have been used to assess the effect of foul play on injury rate (Hawkins and Fuller 1996; Hawkins and Fuller 1998b). These studies did not describe injury situation in detail, and did not have access to detailed medical information of the injuries. However, by using systematic video-based methods it may be possible to combine football-specific and medical information and provide a more complete description of the injury mechanisms and events leading up to injury-risk incidents in football.

Contact injuries

In elite players contact injuries represents for 33-42% of all acute injuries (Hawkins and Fuller 1999; Hawkins et al. 2001). Only Luthje et al. (Luthje et al. 1996) found much higher proportion of contact injuries (79%) (Table 3). Studies on players at lower or various level reports that 55-59% of acute injures were contact injuries, while the comparable percentage for junior players was 42-53% (Ekstrand and Gillquist 1983a; Nielsen and Yde 1989; Hawkins and Fuller 1999; Ostenberg and Roos 2000; Heidt, Jr. et al. 2000; Chomiak et al. 2000) (Table 3).

Tackling has been shown to be the most common injury mechanism in football (Nielsen and Yde 1989; Yde and Nielsen 1990; Luthje et al. 1996; Hawkins and Fuller 1999; Hawkins et al. 2001) (Table 3). Studies on elite players have shown that tackling is responsible for 21-39% of acute injuries (Luthje et al. 1996; Hawkins and Fuller 1999; Hawkins et al. 2001), while for junior players this rate is 40-48% (Nielsen and Yde 1989; Yde and Nielsen 1990; Hawkins and Fuller 1999). Studies have also indicated that tackling is the most usual injury mechanism for ankle (43-67%) and knee (55%) injuries (Nielsen and Yde 1989; Yde and Nielsen 1990).

Heading is a common situation in football. Head injuries represent 4-5% of acute injuries in football (Hawkins and Fuller 1999; Peterson et al. 2000), and most of these occur during contact with another player, for example during heading (Barnes et al. 1998; Boden et al. 1998). However, few studies exist on the mechanisms of head injuries in football. Two studies (one retrospective and one prospective) show that collision with another player is the most usual mechanism for concussion, and such collisions account for an even larger proportion of concussions in female players (71-75%) than in males (47-65%) (Barnes et al. 1998; Boden et al. 1998). Of these, head-to-head contact has been shown to be the most common mechanism (28% of the total number of concussions), followed by head to elbow contact (14%) (Boden et al. 1998). A larger proportion of collisions with other objects than players occurred among male players (35-53%) than females (25-29%) (Barnes et al. 1998; Boden et al. 1998), and most of them occurred when a player was hit in the head by the ball (24% of the total number of concussions), followed by head to ground contact (14%) (Boden et al. 1998). However, the low number of concussions in one of these studies can affect the results and the retrospective design of the other study can also affect the precision of the data.

Table 3. Studies performed on the mechanisms for acute injuries in football.

Citation	Study design	Injuries studied	Gender	Contact injuries		Non-contact injuries			Acute injuries
				Total	Tackling	Total	Sprinting	Shooting /kicking	n
Elite players									
Woods et al. (2003)	Pro-spective	Ankle sprains	Male	59%	54%	39%			1011 *
Woods et al. (2002)	Pro-spective	All injuries	Male		1469 (24%)		1143 (19%)	538 (9%)	6030 *
Hawkins et al. (2001)	Pro-spective	All injuries	Male	1886 (33%)	1469 (25%)	3907 (67%)	1143 (20%)	538 (9%)	5793
Hawkins and Fuller (1999)	Pro-spective	All injuries	Male	221 (42%)	206 (39%)	305 (58%)	126 (24%)	53 (10%)	526
Luthje et al. (1996)	Pro-spective	All injuries	Male	232 (79%)	78 (21%)	62 (21%)			294
Players at lower or various level of play									
Chomiak et al. (2000)	Pro-spective	Severe injuries (>4 weeks)	Male	45 (57%)		34 (43%)			79
Östenberg and Roos (2000)	Pro-spective	All injuries	Female	28 (55%)		23 (45%)			51
Bjordal et al. (1997)	Retro-spective	ACL injuries	Male		56 (42%)				133
			Female		25 (58%)				43

Citation	Study design	Injuries studied	Gender	Contact injuries		Non-contact injuries			Acute injuries
				Total	Tackling	Total	Sprinting	Shooting /kicking	n
Arendt and Dick (1995)	Retro-spective	ACL injuries	Male	34 (52%)		32 (48%)			66
			Female	31 (37%)		53 (63%)			84
Nielsen and Yde (1989)	Pro-spective	All injuries	Male	54 (59%)		38 (41%)			92
Ekstrand and Gillquist (1983a)	Pro-spective	All injuries	Male	104 (59%)		73 (41%)			177
Youth players									
Kakavelakis et al. (2003)	Pro-spective	All injuries	Male	84 (40%)					209 *
Söderman et al. (2002)	Retro-spective	ACL injuries	Female	190 (48%)					398
Heidt, Jr. et al. (2000)	Pro-spective	All injuries	Female	36 (42%)		50 (58%)			86
Hawkins and Fuller (1999)	Pro-spective	All injuries	Male	84 (53%)	69 (44%)	74 (47%)	15 (9%)	21 (13%)	158
Yde and Nielsen (1990)	Pro-spective	All injuries	Male		25 (40%)		17 (27%)	5 (8%)	62
Nielsen and Yde (1989)	Pro-spective	All injuries	Male		13 (48%)				27

** Includes both acute and overuse injuries. Acute and overuse injuries are not reported separately in these papers.*

Non-contact injuries

Studies reports that 58-67% of acute injuries in elite male football occurred in non-contact situations, while 41-45% of acute injuries in players at lower or various level and 47-58% of acute injuries in youth players occurred in non-contact situation (Ekstrand and Gillquist 1983a; Nielsen and Yde 1989; Hawkins and Fuller 1999; Ostenberg and Roos 2000; Heidt, Jr. et al. 2000; Chomiak et al. 2000; Hawkins et al. 2001) (Table 3).

Sprinting is the most usual non-contact injury mechanism, accounting for 20-24% of acute injuries in elite players and 9-27% in youth players (Yde and Nielsen 1990; Hawkins and Fuller 1999; Hawkins et al. 2001) (Table 3). Muscle strains occur most frequently during sprinting, especially hamstring strains (Nielsen and Yde 1989).

Shooting and kicking the ball have found to be the mechanism of 9-10% of acute injuries in elite players and 8-13% in youth players (Yde and Nielsen 1990; Hawkins and Fuller 1999; Hawkins et al. 2001) (Table 3). These are mainly muscle strains in the quadriceps and groin (Nielsen and Yde 1989). Other mechanisms for non-contact injuries as pivoting, falling, slipping etc. are less frequent.

Mechanisms for anterior cruciate ligament injuries

Injury mechanisms for anterior cruciate ligament injuries are of considerable interest, because of the severity and expense of such injuries. Unfortunately, relatively little is known about the exact mechanisms of such injuries in football (Delfico and Garrett, Jr. 1998). Studies have shown that among male players, approximately half of the ACL injuries occur during contact with another player and half in non-contact situations (Arendt and Dick 1995). Similar figures have been reported for females in one study (Soderman et al. 2002), but another study found a higher proportion of ACL injuries in females from non-contact situations (Arendt and Dick 1995) (Table 3). Delfigo and Garrett (Delfico and Garrett, Jr. 1998) indicate in their review of mechanisms of ACL injuries in football players that most contact-induced ACL ruptures occurred during valgus stress, although varus mechanisms have also been reported. They also conclude that the majority of non-contact ACL injuries occur during rapid deceleration, pivoting with internal or external rotation, or landing with varus or valgus collapse of the knee.

From this, one can see that relatively little is known about specific injury mechanisms in football. For example we know from previous studies that tackling is the most usual cause of contact injuries, but we have no information on the playing situation leading up to the tackling, how the tackling was performed, the exposed player movements and attention at the tackling moment, etc. This information is important for developing of preventive measures. Therefore, further studies are needed on this topic to clarify mechanisms of injuries in football.

Prevention of injuries

Injury prevention is of great importance in football. However, as seen above, the knowledge of risk factors and injury mechanisms is limited. Therefore, relatively few studies have been performed to test the effect of specific preventive measures in football. Some studies based on multifactorial prevention programs have been performed. These studies have tested their effect on overall injury rate using different approaches (Ekstrand et al. 1983a; Heidt, Jr. et al. 2000; Junge et al. 2002). The problem with the interpretation of these studies is that it is not known which program component is effective. Other studies have focused on special injury types, in particular ankle sprains (Tropp et al. 1985a; Surve et al. 1994; Soderman et al. 2000) and ACL injuries (Caraffa et al. 1996; Soderman et al. 2000).

Ekstrand et al. (Ekstrand et al. 1983a) performed the first block-randomized controlled study of injury prevention in football. Six male teams of 15 players each participated in an intervention group and six teams in a control group. The intervention group used a multifactorial prevention program before and during one season, consisting of provision of optimum equipment, prophylactic ankle taping, controlled rehabilitation, exclusion of players with severe knee instability, information on the importance of disciplined play and increased risk of injuries in training camps, as well as correction of training and supervision by doctors or physiotherapists. The results showed a 75% reduction of injuries in the intervention group (23 injuries) compared to the control group (93 injuries), which received no intervention or instruction. The injury reduction was significant for overall injury rate and for all main injury types (ankle sprains, knee sprains and muscle strains), the number of operations and absence from match and training. Furthermore, no recurrent injuries were seen in the intervention group, compared with 31 of 93 injuries in the control group.

Heidt et al. (Heidt, Jr. et al. 2000) tested the effect of a preseason training program for female high school players. An intervention group of 42 randomly chosen players performed a multifactorial program based on sport-specific cardiovascular conditioning, plyomeric training, sport cord drills, strength training and flexibility training. During the season, the intervention group incurred significantly fewer injuries (7 injuries in 42 players) than the control group (91 injuries in 258 players).

Junge et al. (Junge et al. 2002) performed a prospective cohort study on junior football players. The intervention group (101 players) used a multifactor program designed to reduce the incidence of football injuries in general. The program was based on improvement of the structure and content of the training with education and supervision of the coaches and players, such as improvement of warm-up, regular cool down, taping of unstable ankles, adequate rehabilitation, promoting fair-play, as well as improvement of joint stability, flexibility, strength, coordination, reaction time and endurance using the F-MARC Bricks (Rosch et al. 2000). The control group (93 players) received no program or supervision. Among the low-skilled teams the injury incidence per 1000 hours of exposure was lower in the intervention group compared to the control group. This was especially seen for minor injuries and injuries occurring during training. No such difference was seen in the high-skill group.

Prevention of ankle sprains

Tropp et al. (Tropp et al. 1985a) studied 450 male football players from 25 teams, and followed them for six months (preseason and spring season periods). They were divided in three groups – seven teams were offered ankle orthoses, eight teams used wobble board training and 10 teams served as control. The results showed that among players with a history of previous ankle sprains, a significantly lower rate of ankle sprains was found in players that used ankle orthoses (2% of players incurred ankle sprains) or wobble board training (5%), compared with the control group (25%). No difference was found in the incidence of ankle sprains between the three groups among players without a history of previous ankle sprains.

Surve et al. (Surve et al. 1994) found in a randomized controlled trial of 504 male football players that the incidence of ankle sprains was significantly reduced in an intervention group with previously injured ankles that used an ankle orthosis, compared to a control group with previously injured ankles that did not use ankle orthosis. No protective effect was seen among players without a history of ankle sprain.

Söderman et al. (Soderman et al. 2000) tested the effect of wobble board training on injuries in the lower extremities among female football players during one outdoor season. 62 players completed the intervention program and 78 players were in the control group. No difference was found in injury incidence between the two groups, neither for lower leg injuries nor for specific injury types such as ankle or knee injuries.

Prevention of ACL injuries

Caraffa et al. (Caraffa et al. 1996) studied 40 male football teams including 600 players in a prospective controlled study, 20 teams in the intervention group and 20 control teams. The intervention group used a training program based on proprioceptive wobble board training, both during the preseason period and during the season, while the control group just did their ordinary football training. They found that the teams that used the training program incurred significantly fewer ACL injuries (0.15 injures per team/season) than teams that did not use this training program (1.15 injures per team/season).

In summary, only seven studies are found on preventive measures in football and although the results are very promising, few evidence-based methods are available to prevent injuries in football. Moreover, most of the programs are general and not specific to football. The main reason for this may be our limited understanding of risk factors and injury mechanisms in football. Studies have shown that prevention programs can decrease injury risk, but in these studies we do not know exactly which of the factors cause the preventive effect (Ekstrand et al. 1983a; Heidt, Jr. et al. 2000; Junge et al. 2002).

Aims of the study

The aims of the present study on Icelandic elite male football players were to investigate:

1. The incidence, as well as the type, location and severity of injuries (papers I & II).

2. Whether different factors (age, body size, body composition, range of motion, leg extension power, jumping ability, peak O_2 uptake, ankle or knee instability, previous injury, player exposure, or playing surface) could be identified as risk factors for injuries (papers I & II).

3. The relationship between team physical fitness, injuries and team performance (paper III).

4. The differences in physical fitness between different player positions (paper III).

5. The characteristics of injury-risk incidents and injury situations (paper IV).

6. The effectiveness of a video-based awareness program on the incidence of acute injuries (paper V).

Material and methods

This thesis is based on five papers with results from studies which span a period of 10 years: 1991 (Paper I), 1999 (Paper II, III, IV) and 2000 (Paper V). The study design is shown in Figure 2.

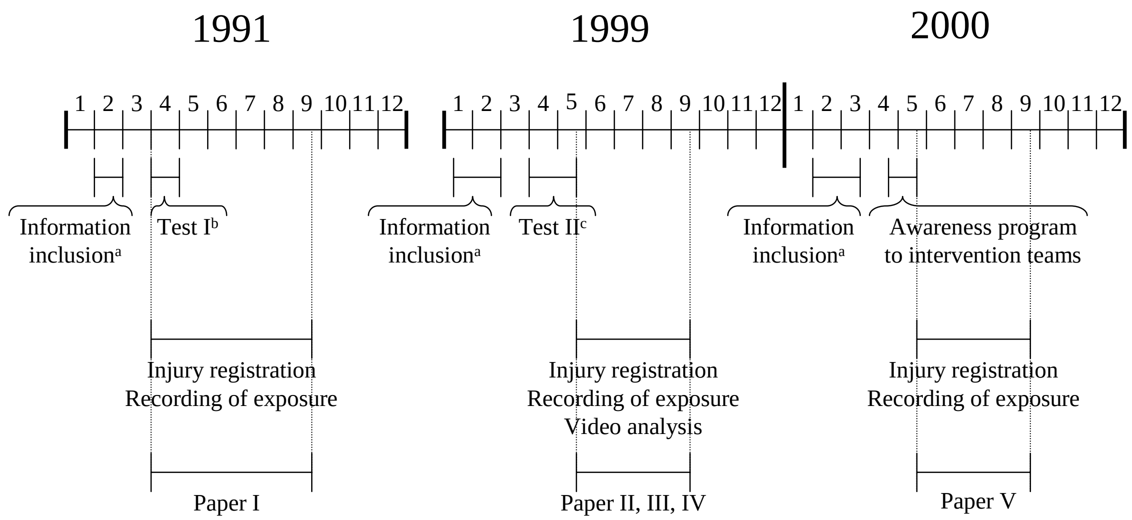

Figure 2. Design of the study.

[a]Before the start of each study period coaches, team physical therapists and the team managers received information about the study and an invitation to participate.

[b]Test I included tests of flexibility, mechanical stability of ankles and knees, as well as a questionnaire about previous injuries.

[c]Test II included tests of peak O_2 uptake, body composition, leg extension power, jump height, flexibility, ankle and knee stability, as well as a questionnaire about previous injuries.

Paper I

Participants

The football season in Iceland lasts from mid-May until mid-September. Ten male teams participated in the Icelandic elite football league during the 1991 season, and five of them, with a total of 84 players, participated in the study. The selection of teams was based on geographical distribution and the final league standing of the teams during previous seasons.

Tests

In April the players were tested with regard to flexibility and mechanical stability of the ankles and knees. All of the tests were performed by one experienced physical therapist. The players also answered a questionnaire about previous injuries. Range of motion (ROM) was measured in accordance with Ekstrand et al. (Ekstrand et al. 1982), for hamstrings, adductors, rectus femoris, hip flexors, and ankle plantar flexors. Lateral ligament stability in the ankles was tested with anterior drawer and talar tilt tests and a medial stability test was also performed. For the knees, valgus and varus tests were performed, as well as Lachman and posterior drawer tests (Arnheim 1989).

Injury registration

From April 1st until the end of the season, team physical therapists, physicians or coaches registered injuries prospectively on a special form, which was collected once a month. This form included information about the type and location of the injury, former similar injuries, the injury mechanism, duration of the injury and the exact diagnosis. During the same time period, the coaches recorded individual match and training exposure, i.e. player participation for every match and training session (including the duration of each session) on a special form. A player was defined as injured if he was unable to participate in a match or a training session because of an injury that occurred in a football match or during training. The player was defined as injured until he was able to play a match or comply fully with all instructions given by the coach, including sprinting, turning, shooting and playing football at full tempo (Lewin 1989). The injury severity was classified in four categories according to their duration: less than one week, one to two weeks, two to four weeks, and more than four weeks.

Papers II-IV

Participants

Twenty male football teams participated in the Icelandic elite league and first division during the 1999 football season, and 17 of these (nine from the elite league and eight from the first division) accepted an invitation to participate in this study. A total of 306 players (mean age 24, range 16-38 yrs) were followed. Just before the start of the season, the players performed a series of testing procedures and answered a questionnaire about previous injuries to establish base-line information on potential risk factors for injury. The testing procedures included the following: Peak O_2 uptake (226 players completed this test), body composition (n=228), power testing (n=215), jump tests (n=217), flexibility tests (n=249), ankle and knee stability tests (n=257), and a questionnaire (n=257). A total of 153 players participated in all of the tests and 301 players took part in at least one of the tests. All of the tests of each type were conducted by the same person. A detailed description of each of the tests is found in paper II.

Peak O_2 uptake

The players were tested on a treadmill. During the first three minutes the speed was gradually increased to 70-80% of maximal heart rate and then maintained for the next three minutes. After a three minute break, which included stretching, he was connected to a mouth/nose piece and O_2 uptake and CO_2 production measured while he ran for about two minutes at same speed as the final speed during the warm up period. Then the speed was increased by 0.5 m/s every minute until 4 m/s was reached, and after that the inclination of the treadmill was increased by 1.5° every minute until volitional exhaustion. O_2 uptake and CO_2 production was measured using test instruments from VacuMed, Ventura, USA. Heart rate was measured using a Polar Sport Tester PE 4000 pulse meter.

Body composition

Skin-fold measurements were taken from six different areas; triceps brachii, subscapular, pectoralis major, iliac crest, abdomen and anterior thigh (Lange Skinfold Caliper from Cambridge Scientific Industries Inc. Cambridge, Maryland, USA), and body mass measured. Body composition (% body fat) were calculated using the average of four commonly accepted formulas (Siri 1956; Jackson and Pollock 1978; Jackson and Pollock 1985; Golding et al. 1989). Body mass index (BMI, $kg \cdot m^{-2}$) was calculated as the body mass (kg) divided by the squared height (m^2).

Leg extension power

Maximal average power was measured in the extension phase of a squat in a slide machine with a guided horizontal barbell (MultiPower, TechnoGim, Torreveccia Teatinge, Italy). A MuscleLab unit (Ergotest Technology a.s., Langesund, Norway) was connected to the slide machine with a linear encoder (ET-Enc-01, Ergotest Technology a.s., Langesund, Norway), which measures vertical movement of the bar as a function of time. After a few practice runs, the player rested the bar on his trapezius, took a deep breath and bent his hips and knees to 90º, stopped observably for 1-2 s, and then extended his hips and knees as fast as possible. Tests were performed with an external load of 20, 40, 60 and 80 kg, with two attempts at each load.

Jumping ability

Jump tests were performed on a contact mat (PE, TapeSwitch Corp., New York, USA) connected to the MuscleLab unit, which measures the height of rise of the center of gravity above the ground (*h*, cm) based on the flight time (t_f, s) with the formula: $h = t_f^2 \cdot g \cdot 8^{-1}$ (Bosco et al. 1995). Three types of jumps were tested: standing jump (SJ), countermovement jump (CMJ), and one-leg countermovement jump (CMJ one).

Flexibility

Flexibility was measured as static range of motion (ROM) for the hamstrings, adductors, rectus femoris, and hip flexors. For each test the players were fixed on an examination table with belts to avoid accessory movements. The predetermined movement was carried out with the same load for each player, measured with a tension meter (MIE Medical Research Ltd., Leeds, England) or a Myometer (Penny & Giles Transducers, Christchurch, England). ROM was measured based on photos taken with a JVC digital camera and analyzed using the KineView movement analysis system (Kine, Reykjavik, Iceland), except for hip abduction, which was measured with double-armed goniometer.

Mechanical instability

The mechanical stability of ankles and knees was tested manually (by one experienced physical therapist) and for each test the players were classified stable or unstable. For the ankle the anterior drawer and talar tilt tests for lateral stability, as well as a medial stability test were performed. For the knee the Lachmann test, a valgus test for medial stability, a varus test for lateral stability, and a posterior drawer test were performed (Arnheim 1989; Magee 1992).

Injury registration

Injuries were recorded prospectively throughout the season by the team physical therapist on a special form, which included similar factors as during the 1991 study. The forms were collected once a month. Coaches registered player exposure during training on a special form, while official records were used to monitor match exposure. The same injury definition was used as in 1991, but injury severity was classified in the following three categories according to the duration of absence: mild (1-7 days), moderate (8-21 days) and severe (more than 21 days). Acute injuries were defined as injuries with a clear onset as a result of trauma (for example tackling, kicking, or sprinting). Overuse injuries were defined as injuries with an insidious onset with a gradually increasing intensity of discomfort without an obvious trauma (Wikstrom and Andersson 1997).

Video recordings

During the 1999 football season, videotapes of 52 matches from the elite league teams were made available by the Sports Department of the Icelandic National Broadcasting Service – Television. These videotapes were reviewed and injury-risk incidents were transferred to a master videotape for further analyses. An injury-risk incident was defined as a situation where the match was interrupted by the referee, a player lay down on the pitch for more than 15 s, and the player appeared to be in pain or received medical treatment (Andersen et al. 2003). A football expert analyzed the master videotape using Football Incident Analysis (FIA, see paper IV for details). The FIA is a new method developed at Oslo Sports Trauma Research Center, and combines football-specific and medical information to provide a more complete description of the injury mechanisms and events leading up to incidents in football (Andersen et al. 2003).

Paper V

Participants

Before the start of the 2000 football season, 17 male football teams in the elite and first divisions accepted an invitation to participate. Of these, eight teams were randomly chosen to participate in the intervention group, the others served as controls.

Intervention program

Just prior to the start of the season, the teams in the intervention group were visited individually with an intervention program based on a 15-minute presentation, including information about the study, the injury risks associated with playing elite football, and typical injury mechanisms. Then a process of guided discovery as described by Ettlinger et al. (Ettlinger et al. 1995) was used to increase player awareness of injuries and their mechanisms. The players worked together in pairs and were asked to analyzed 12 video sequences from the 1999 football season and describe strategies whereby the incident could be prevented. The video sequences were selected to represent three categories of injury mechanisms that were found to account for 57% of all incidents during the previous season (paper IV). The teams in the control group were not provided with any information on the content of the intervention program, on the injury risk in football, common injury types, or on injury mechanisms.

Injury registration

Injuries and time exposure during matches and training were recorded as during the previous seasons. Two of the 17 teams (one from the intervention group and one from the control group) did not follow up the injury registration, and had to be excluded from the study.

Statistical methods

Generally, the data are described as mean values and the standard deviation (SD) or standard error of the mean (SEM) were used as measures of variability. SPSS (version 10.0; SPSS Inc., Chicago, Illinois, USA) was used for the statistical analyses. A p-value ≤ 0.05 was considered statistically significant.

A group average coefficient of variation (CV%) for paired measurements (Friedlander et al. 1991) was used to report the intrarater reliability of flexibility tests in paper II.

An independent sample t-test was used in paper I to compare possible difference in ROM between injured and non-injured players. Independent sample t-tests were also used in paper III to compare test results between players in the elite and first division, and to compare the team average for each test variable between the two divisions.

A one-way ANOVA was used in paper III to test for possible differences in test variables between different player positions (goalkeepers, defenders, midfielders and strikers). The same method was also used to test for differences between goalkeepers and field players, and between the three different positions of field players, using Bonferroni correction for multiple comparisons.

A univariate logistic regression analysis was used in paper II to compare uninjured and injured group of players treating potential risk factors as continuous or categorical variables. All variables with p-value ≤ 0.20 were entered in a backward stepwise multivariate logistic regression analysis to evaluate potential predictor variables. For the categorical analyses, the players were grouped for each variable in three groups. The odds ratio (OR) and 95% confidence interval (95% CI) were calculated for the groups of players with the lowest (>1 SD below the mean) and the highest (>1 SD above the mean) values for each variable, respectively, with the intermediate group of players as the reference group.

A linear regression analysis was used in paper III to test for a possible relationship within divisions between team averages (independent variable) and the final league standing of the teams (dependent variable). The common slope for both divisions corrected for division was calculated and unstandardized regression coefficient (B) was used to describe the slope. A linear regression analysis was also used in paper V, to test if the slope for monthly injury incidence during the season was different from zero. This test was also done separately per group.

A Z-test was used in paper II to calculate the difference in injury rate between the elite league and first division, and in paper V to compare ratios (number of injuries/hours of exposure) between, and within groups.

A chi^2-test was used in paper I to compare the incidence of injuries between stable and unstable ankles and knees, and in paper IV to compare the injury distribution during different time periods of the matches, as well as between the attacking and defending phase of play. A chi^2-test was also used in paper V to test for differences in injury distribution between the intervention and control group, and to test for differences between groups in injury severity.

Results and discussion

Incidence of injuries

The injury incidence in Icelandic elite football is high (Table 4). During the 1991 study period (paper I), one acute time-loss injury occurred every 0.8 matches and 16.0 training sessions. The corresponding number for the 1999 season (paper II) was one injury every 1.2 matches and 19.3 training sessions, and for the control group during the 2000 season (paper V) similar results were found (one acute injury every 1.0 match and 21.9 training). No significant difference was seen in the incidence of acute injuries between the 1991, 1999 and 2000 (control group) studies. Despite of methodological differences, such as in the injury definition used, registration methods, duration of the registration, and the level of play, the incidences observed are similar to those seen in most comparable studies from other countries (Ekstrand and Tropp 1990; Hawkins and Fuller 1999; Morgan and Oberlander 2001; Hagglund et al. 2003; Ekstrand et al. 2004). However, recent studies report a higher incidence of injuries at the national team level (Yoon et al. 2004; Junge et al. 2004a; Junge et al. 2004b), especially during lost matches (Ekstrand et al. 2004). Studies have also shown that football has a higher injury rate than most other sports (de Loes 1995; Bahr et al. 2003). A high risk of injuries is therefore a global problem in football, affecting the individual as well as team performance. Injuries are also costly for professional football clubs, because of sick-listed players, rehabilitation costs and even the possibility of having to buy new players to replace injured players.

Table 4. Incidence of acute time-loss injures among elite male football players in Iceland during the three study periods.

	1991 (Paper I)	**1999 (paper II)**	**2000 (paper V) (control group)**
Match	33.0 ± 3.4	24.6 ± 2.0	26.0 ± 3.0
Training	5.3 ± 1.0	2.1 ± 0.3	1.9 ± 0.4
Total	11.6 ± 1.1	6.1 ± 0.4	6.6 ± 0.7

During the five and half month period of the 1991 study, 60 (71%) of the 84 participating players incurred a time-loss injury (acute or overuse) (paper I), compared to 170 (56%) of the 306 players in the 1999 study (paper II) and 59 (46%) of the 127 players that completed the 2000 study (control group only, paper V). Other studies have reported that 65 – 91% of the players were injured during either one season or one year (Ekstrand and Gillquist 1983a; Eriksson et al. 1986; Nielsen and Yde 1989; Lewin 1989; Luthje et al. 1996; Hawkins et al. 2001; Hagglund et al. 2003). In the 1999 and 2000 studies, injuries were registered just during the competitive season, which lasts for only four months in Iceland. In previous comparable studies the study period was longer (9 – 12 months), which means that the players were at risk of injury for longer period of time and therefore it is not surprising that a higher percentage of players were injured. These results confirm that the injury risk in elite football is high, and suggest that during a full calendar year, including the competitive season as well as the pre-season preparation period, most players will suffer from at least one time-loss injury.

Injury severity is another concern. In 1999 (paper II), 39% of injuries were minor (time-loss lasted 1-7 days), 38% moderate (8-21 days), and 23% severe (more than 21 days). This means that one severe injury occurred in every 5.5 matches and 75.9 training sessions. For the 2000 season (control group only) the results were very similar, one severe injury occurred in every 7.5 matches and 80.3 training sessions. However, a comparison with previous studies is difficult because of differences in injury definitions and severity classification.

Type and location of injuries

Most studies conducted in the 1980s found that ankle sprains was the most common injury type, followed by knee sprains or hamstring strains (Ekstrand and Gillquist 1983a; Nielsen and Yde 1989; Lewin 1989; Ekstrand and Tropp 1990; Engstrom et al. 1990). The more recent studies indicate changes in this injury profile, in such way that the proportion of hamstring strains seems to have increased, and the rate of hamstring strains has become equal to or even higher than for ankle sprains (McGregor and Rae 1995; Hawkins and Fuller 1999; Hawkins et al. 2001). The same pattern is seen in our studies. During the 1991 season (paper I), hamstring strains and ankle sprains were the most frequent injuries (16% and 15% of the total number of injuries), followed by anterior thigh contusions (9%) and quadriceps strains (6%), as well as knee sprains (6%) (Table 5). During the 1999 season (paper II), hamstring strains was the most frequent type of injury (13%), followed by groin strains (9%), knee sprains (8%) and ankle sprains (8%). Hamstring strains was also the most frequent injury type during the 2000 season (15%) (paper V), followed by ankle sprains (7%), groin strains (6%) and knee sprains (5%) (Table 5).

Table 5. Total injury incidence (match and training injuries combined) of the four most usual injuries during the 1991 (paper I), 1999 (paper II) and 2000 study periods (paper V, control group only).

	1991	**1999**	**2000 (control group)**
Hamstring strains	1.5 ± 0.5	0.9 ± 0.2	1.0 ± 0.3
Groin strains	0.4 ± 0.2	0.6 ± 0.1	0.4 ± 0.2
Knee sprains	0.5 ± 0.2	0.6 ± 0.1	0.4 ± 0.2
Ankle sprains	1.3 ± 0.4	0.6 ± 0.1	0.9 ± 0.2

The injury profile in football appears to have changed since the 1980s. Hamstring strains have become more frequent than previously (Ekstrand and Gillquist 1983a; Nielsen and Yde 1989; Lewin 1989). Possibly, this reflects the evolution of the game into a faster or more demanding pace with more fit players who may be better sprinters and therefore at greater risk for hamstring strains. The incidence and percentage of ankle sprains were lower during 1999 and 2000 seasons than reported in paper I or previous studies (Ekstrand and Gillquist 1983a; Lewin 1989; Ekstrand and Tropp 1990; Engstrom et al. 1990; Hawkins and Fuller 1999). The decrease in the frequency of ankle sprains can possibly be explained by increased knowledge about preventive measures, such as balance and strength training of functionally unstable ankles and prophylactic ankle taping as instituted by Tropp et al. (Tropp et al. 1985a), as well as more emphasis on the treatment and rehabilitation after ankle sprains. The rate of knee injuries observed was in accordance with previous studies (Ekstrand and Gillquist 1982; Ekstrand and Gillquist 1983a; Nielsen and Yde 1989; Lewin 1989; Hawkins and Fuller 1999; Hawkins et al. 2001).

Risk factors for injuries

During the 1999 study, a number of risk factors were tested:

Previous injuries

In paper II, a previous hamstring or groin strain and a previous ankle or knee sprain were found to be strong predictors for new injuries on the same side based on a univariate analysis (Figure 3A and 3B). This was confirmed in a multivariate analysis for hamstring and groin strains (Table 6), while for ankle and knee sprains a multivariate analysis could not be performed, since no other factor than previous injury reached the cut-off value for inclusion in a multivariate analysis. The effect of previous injury as a risk factor was also indicated in the 1991 study (paper I), where recurrent strains in the hamstrings and groin were common, as were recurrent ankle and knee sprains. Previous studies have also shown high frequency of recurrent strains in the hamstrings (Nielsen and Yde 1989; Hawkins and Fuller 1999) and groin (Ekstrand and Hilding 1999), as well as recurrent sprains to the ankle (Ekstrand and Gillquist 1983a; Nielsen and Yde 1989; Hawkins and Fuller 1999; Holme et al. 1999) or knee (Ekstrand and Gillquist 1983a). The reason for the high frequency of recurrent hamstring and groin strains can be structural changes or scar tissue formation in the muscle or tendon after injury (Noonan and Garrett, Jr. 1992; Jarvinen et al. 2000). Such tissue changes may cause decreased strength, elasticity, or neuromuscular coordination directly, or reduced function may be a result of immobilization, missed training and inadequate rehabilitation during the period of missed training participation. Reduced neuromuscular control of the ankle joint is seen in patients with persistent instability complaints after ankle injury (Tropp et al. 1985b; Konradsen and Ravn 1991; Karlsson et al. 1992), while other studies report a high frequency of mechanical instability (Ekstrand and Gillquist 1982; Ekstrand and Gillquist 1983a; Brynhildsen et al. 1990). Both of these factors, independently or in combination can increase the risk of new ankle sprains (Tropp et al. 1984; Beynnon et al. 2001).

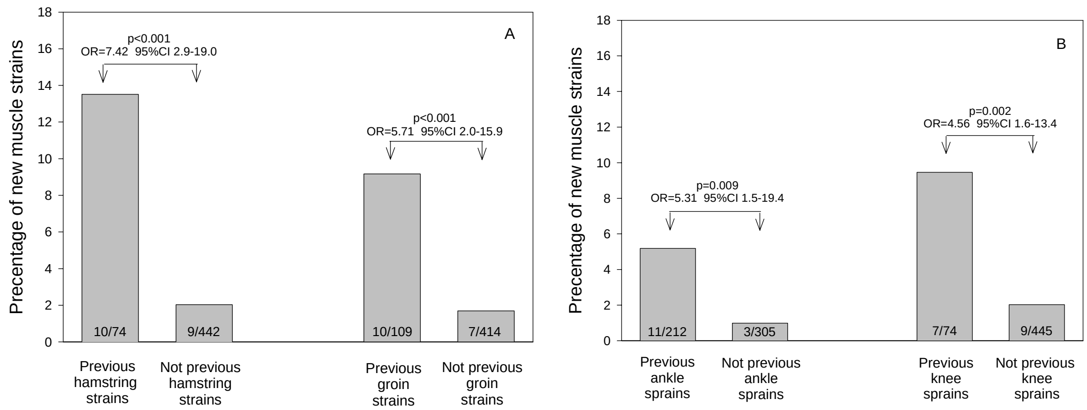

Figure 3. Comparison of the risk of new hamstring and groin strains (A), as well as ankle and knee sprains (B), among players that previously had sustained such an injury, and players with no previous injury (paper II). Each leg has been treated as a separate case. P-values were obtained using univariate logistic regression. Odds ratios (OR) are presented with 95% confidence intervals.

Table 6. Significant predictor variables for injuries in football from the multivariate logistic regression analysis (paper II). Odds ratio, 95% confidence interval for the odds ratio and p-values are shown for each variable.

Variable	**OR**	**95% CI**	**p**
Injured – not injured			
Increasing age (one year)	1.1[a]	1.0 – 1.1	0.05
Hamstring strains			
Increasing age (one year)	1.4[b]	1.2 – 1.4	<0.001
Previous hamstring strains	11.6[b]	3.5 – 39.0	<0.001
Groin strains			
Previous groin strains	7.3[c]	2.3 – 23.2	0.001
Decreased ROM in hip abduction (one degree)	0.9[c]	0.8 – 1.0	0.05

[a] *Estimated per person for one year increase in age. The estimate was obtained when age and exposure hours in matches were included in the multivariate model.*

[b] *Estimated per leg, when previous hamstring strains, age, weight and body composition (% fat) were included in the multivariate model.*

[c] *Estimated per leg, when previous groin strains, the amount of hip abduction and hip extension were included in the multivariate model.*

Age

In paper II, age was found to be a significant risk factor for injuries in general and for hamstring strains separate, both in univariate and multivariate analysis (Table 6). The oldest age group (>1 SD above mean, 29-38 years) also had a significantly higher risk of injuries than the intermediate group, both for injuries in general (p=0.004), as well as for hamstring strains (p=0.02). This is in accordance with a previous studies on male and female football players (Lindenfeld et al. 1994; Ostenberg and Roos 2000), but others report no such trend (Dvorak et al. 2000; Chomiak et al. 2000; Soderman et al. 2001b). Some factors could possibly predispose older players to be more prone to injuries, e.g. longer career duration (Ostenberg and Roos 2000), increased number of previous injuries or cumulative microtrauma, as well as degenerative changes. Using multivariate analysis (paper II), previous hamstring strains were found to be a confounder for age, which means that previous hamstring strains increase the effect of age as a risk factor for new hamstring strains. This indicates the importance of previous hamstring strains as risk factors for new hamstring strains.

Joint stability

In the 1991 study (paper I), significantly more injuries occurred in knees with medial instability than in stable knees (p<0.02). No such relationship was found between mechanical unstable ankles and ankle sprains in 1991 (paper I), nor was there any correlation between mechanical ankle or knee instability and the risk of sprains in the same joints during the 1999 study (paper II). However, Chomiak et al. (Chomiak et al. 2000) found some correlation between knee joint laxity based on a Lachman test, valgus and varus stress tests and non-contact knee injuries. Beynnon et al. (Beynnon et al. 2001) also reported an association between increased talar tilt and an increased incidence of ankle injuries, while others reported no such relationship (Barrett et al. 1993; Baumhauer et al. 1995). These results are controversial, and it is difficult to draw firm conclusions about the effect of mechanical instability on injury risk. The methods used during testing also differ and a multivariate approach has not been used. Functional instability is also shown to be a risk factor for ankle sprains (Tropp et al. 1984), but just one fourth of ankles with mechanical or functional instability display both types of instability (Tropp et al. 1985b). During recent years increased information on the importance of preventive measures for ankle and knee sprains has improved the general knowledge of coaches and football players about the role of neuromuscular control in joint stability, which could have resulted in an increased emphasis on balance training and therefore possibly decrease the risk of injury.

Flexibility

In paper I, no relationship was found between flexibility and injuries. In paper II, a decreased range of motion for hip abduction was found to be a significant risk factor for groin strains (Table 6), while no relationship was shown between flexibility and hamstrings, quadriceps or hip flexor injury. This is in accordance with Ekstrand et al. (Ekstrand and Gillquist 1983b), who found that players that were less flexible for hip abduction incurred significantly more muscle strains or overuse injuries in the groin during the season, but other studies have not confirmed these results (Watson 2001; Witvrouw et al. 2003). However, in contrast with other studies (Orchard et al. 1997; Watson 2001; Soderman et al. 2001b), Witvrouw et al. (Witvrouw et al. 2003) found by using univariate analysis, that football players with increased muscle tightness in hamstring and quadriceps incurred significantly more hamstring and quadriceps muscle injuries during the following season. In multivariate analysis only short hamstring muscles was found to be a significant risk factor for hamstring injuries. It is interesting that although decreased flexibility is commonly thought to increase the injury rate in football, just a few studies are found that indicate such correlation. The reason can be that most studies are small and decreased flexibility is only one of many factors that can make a football player more prone to injuries, which indicate the importance of a multifactorial approach in future research that take into account many possible risk factors. The method of measuring flexibility is also critical, and differs between studies. Therefore larger studies are needed to test possible relationship between decreased flexibility, other potential risk factors and injuries in football.

Player exposure

In paper II, players with the highest and the lowest exposure during matches and training (>1 SD above mean, and >1 SD below mean) had at least a trend towards a lower injury rate than the intermediate group ($p \leq 0.09$, for details see Table 5 in paper II). This is in accordance with Ekstrand et al. (Ekstrand et al. 1983b) who found that teams with an average training volume incurred the highest injury rate, while lower rates were found for those who trained less or more. It is not surprising that players who train and play football for fewer hours incurred fewer injuries, because they were less exposed. Ekstrand et al. (Ekstrand et al. 1983b) suggested that players that train and play more are in better physical condition and therefore they incur fewer injuries. Perhaps these players also have better technique, anticipation or awareness of their surroundings which can make them better players, as well as less prone to injury. Players with such qualities are also more likely to be chosen to play by the coach.

Playing surface

In the 1991 study (paper I), playing on artificial turf was found to be a risk factor for injuries, with a significantly higher injury incidence on artificial turf than on grass or gravel ($p<0.01$). No significant difference was found in the injury type pattern between different surface types, possibly because of lack of study power. A higher overall injury rate on artificial turf is in accordance with most previous studies from different sports (Stevenson and Anderson 1981; Powell 1987; Hagel et al. 2003), and previous studies also report a higher rate of ankle and knee injuries on artificial turf than natural grass (Powell 1987; Powell and Schootman 1992). However, it should be noted that the artificial turf available in Iceland during the 1991 study was hard, with high friction, which previously have been documented as the two main surface-related risk factors for injuries in football, as well as in Australian rules football and rugby (Ekstrand and Nigg 1989; Inklaar 1994b; Milburn and Barry 1998; Orchard 2002). High friction limits the movement between surface and shoe, which can increase the risk of ligament sprains and fractures in the ankle, lower leg and knee. Hard surfaces can also increase injury risk from single impacts or repeated submaximal forces, resulting in tissue overload (Ekstrand and Nigg 1989; Inklaar 1994b; Murphy et al. 2003). Furthermore, a hard surface may increase the speed of the game (Norton et al. 2001; Orchard 2002), which possibly could results in more muscle strains and harder collisions. However, more studies are needed on the effect of ground friction and hardness on injury rate in football, at the same time take into account other confounding factors such as wet or dry surface, the amount of rainfall and evaporation, temperature, length of cleats, material and structure of the shoe and surface, as well as level and intensity of play (Orchard 2002).

Factors not identified as risk factors for injuries

A number of candidate fitness factors were tested, but not found to be risk factors for injury. Player height, body mass and body mass index (BMI) were not related to injuries, which is in accordance with previous studies on adult players (Baumhauer et al. 1995; Ostenberg and Roos 2000; Beynnon et al. 2001). No association was found between injuries and leg extension power or jumping ability. Several studies have examined leg power or jumping ability in football players (Gauffin et al. 1989; Wisloff et al. 1998; Rosch et al. 2000; Cometti et al. 2001), but I was not able to find any study on the relationship between leg power and injuries. During the present study peak O_2 uptake was not found to be a risk factor for injuries, and there are no previous studies that have correlated direct measures of maximal O_2 uptake to injury risk. However, two previous studies on injuries in football are found that were based on submaximal tests (Eriksson et al. 1986; Ostenberg and Roos 2000). Erikson et al. (Eriksson et al. 1986) found that players with a higher estimated maximal O_2 uptake incurred more overuse injuries, while Östenberg and Roos (Ostenberg and Roos 2000) found no correlation between estimated maximal O_2 uptake and injuries in female players.

Injuries and physical fitness related to team performance

During the 1999 season (paper III), there was a strong trend towards an inverse relationship between the number of injury days per team and team success (Figure 4). If one outlier team from the elite league (number 10 in the final league standing) was excluded, there was a significant correlation between these variables ($B=20.3 \pm 6.8$, corrected for division, $p=0.01$). This means that if players have many days off because of injuries during the season, the team is less likely to succeed. In Iceland, the number of players per team is often limited and teams often have limited resources to replace injured players. Injuries on key players can therefore affect their playing style and team success more than among teams in the major leagues in Europe, where squads are larger and teams can buy a new quality player when needed. We have not been able to find any previous studies where the relationship between injuries and team performance has been studied systematically.

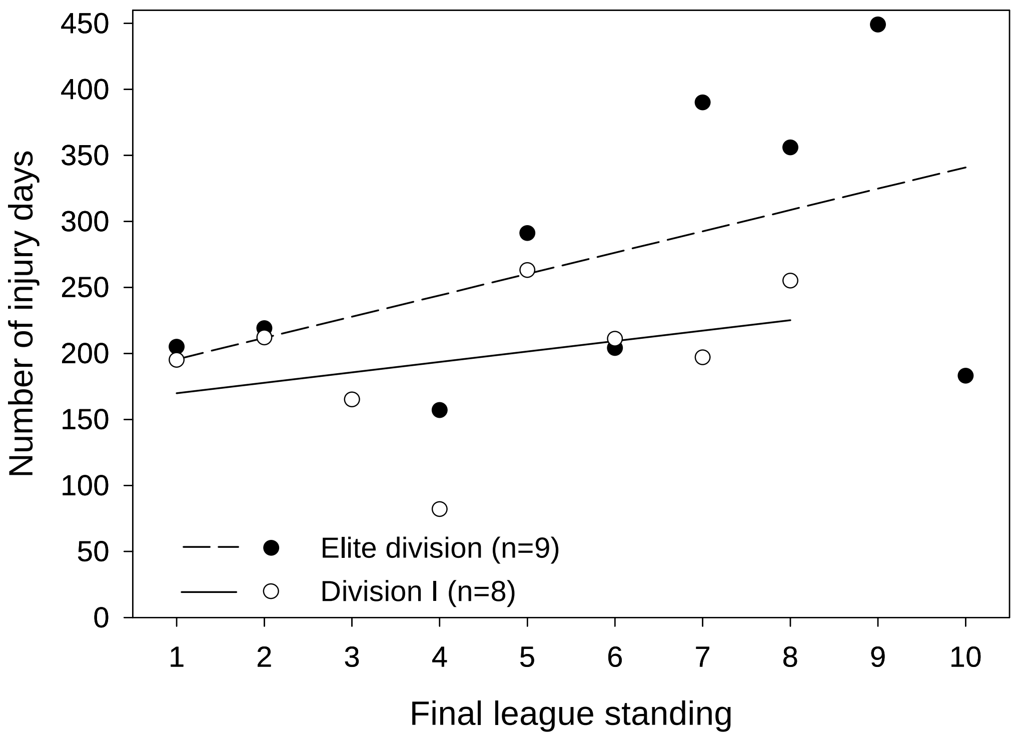

Figure 4. Relationship between number of injury days per team and the final league standing of the teams (B=13.2 ± 7.3, p=0.092, corrected for division).

A significant relationship was found between the team average jumping ability and team success (final league standing) (Figure 5A and 5B). There was also a trend towards a relationship between team success and leg extension power (see Figure 3 in paper III), as well as body leanness (see Figure 4 in paper III). It appears that leg power and jumping ability are important fitness factors influencing team success. Some studies have shown that players at a higher level demonstrate a higher vertical jump height than players at lower levels (Gauffin et al. 1989; Rosch et al. 2000), while other studies did not find such a difference (Wisloff et al. 1998; Cometti et al. 2001). Studies also show that there is a strong correlation between jump height and running speed (Gauffin et al. 1989; Bosco 1999), and that sprinting speed is the main fitness variable differentiating between elite and non-elite football players (Ekblom 1986; Davis et al. 1992).

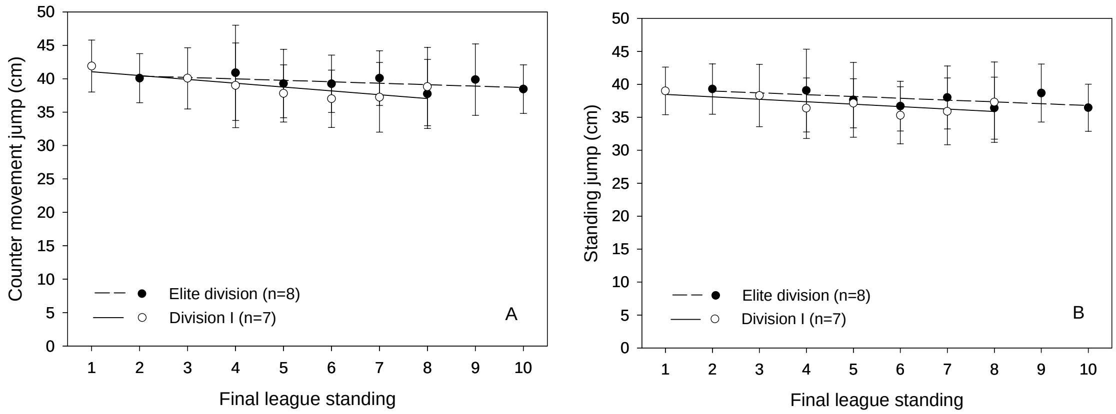

Figure 5. Relation between team average for counter movement jump height (5A), as well as standing jump height (5B) and the final league standing of the teams (counter movement jump: B = -0.36 ± 0.12, p=0.009, and standing jump: B = -0.31 ± 0.12, p=0.012, corrected for division). For both figures error bars are given to show the variation within each team (SD).

There are several potential explanations for the low correlation between most of the physical fitness variables and team performance seen in the present study. Our hypothesis was that the best teams would have a higher average value per all the physical fitness variables and would be more homogenous than the weaker teams. The results showed that only jump height was significantly related to team success and within-team variability was similar for all the fitness test across the league (see figures 1 to 6 in paper III). We were not able to test physical fitness during the season, but one study indicates that there is an increase in physical fitness during the first half of the season (Casajus 2001), so one could hypothesize that the Icelandic players had not reached their peak performance when they were tested just before the season started. However, although the Icelandic football season is relatively short (4 months), the preseason preparation period is long (6-7 months) and includes a hard fitness program, training camps and numerous preseason matches. It clearly seems that the main explanation for the difference in team performance, which is high between the top of the elite division and bottom of the first division, must lie elsewhere. Other factors that are likely to be important in team success include player technique, attention and reaction time as well as psychological factors and team tactics. All these factors and even also chance, can interact with physical fitness and injuries to cause significant differences in success between teams.

Injury mechanisms

During the 52 matches available on video, 95 injury-risk incidents were recorded and analyzed using Football incident analysis (FIA, paper IV). During these matches injuries were registered by the team physical therapists, but only 28 of 52 registered injuries (54%) were identified on video. One likely explanation for this is that during most of these matches only one camera was used, usually following the ball. Injuries that took place at other locations on the field were therefore not usually available on the video, for example hamstring strains that usually take place during sprinting, rapid increase in speed or turning, which does not always take place near the ball. Also minor contusions that did not stop the player from continuing the match, but forced him to miss the next training session because of a hematoma may have been overlooked. On the other hand all registered ankle and knee injuries were seen on the video tapes, but these injuries usually take place near the ball, causing the player to lay down for more than 15 seconds and receive medical attention. Therefore, the FIA can be useful to study the injury mechanisms of some specific injury types as ankle and knee sprains, while lack of data for other types of injuries, such as muscle strains or minor contusions, limits the possibility to study their mechanisms.

Of the 95 incidents, a total of 84 incidents (88%) and 20 injuries (71%) occurred during duels, and in accordance with our study from 1991 (paper I), and previous studies (Luthje et al. 1996; Hawkins and Fuller 1999; Rahnama et al. 2002; Giza et al. 2003; Woods et al. 2003), tackling duels were the most frequent (Figure. 6).

The FIA did not reveal one particular injury mechanism that can account for a large number of incidents, such as that seen for anterior cruciate ligament injuries in alpine skiing (Ettlinger et al. 1995) or team handball (Olsen et al. 2003), or ankle sprains in volleyball (Bahr and Bahr 1997). However, three characteristic playing situations were found to be responsible for 57% of all incidents: a) Break-down attacks with tackling from the side or the front and with the attention focused on the ball (24%), b) Defensive tackling duels with player attention focused on the ball or with low degree of ball control (20%), c) Heading duels with the attention focused on the ball in the air (13%).

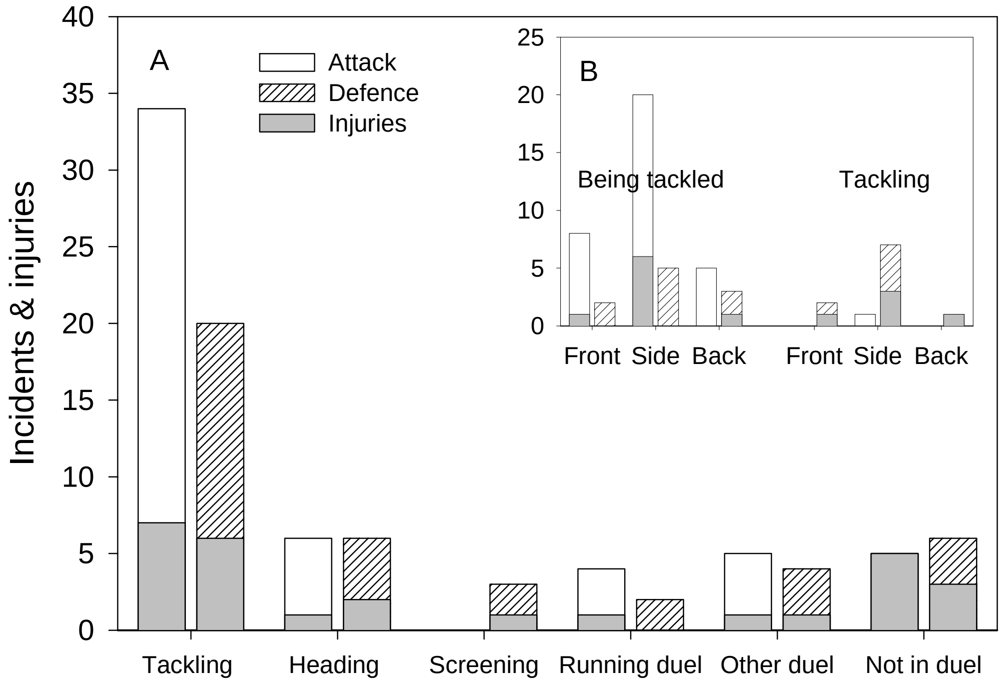

Figure 6. A) Number of incidents (n=95) and injuries (n=28) in different types of duels, which occurred during the attacking or defending playing phase. B) Number of incidents (n=54) and injuries (n=13) that occurred during tackling duels, classified according to the exposed player received a tackling or he tackled another player and the tackling direction.

A break-down attack is when one team loses the ball and the other team immediately starts an attack. In the injury situations seen, most of these attacks started with a short pass with the exposed player's attention focused on the ball, while an opponent tackled him from the side or the front. In nearly half of these situations the exposed player had low degree of ball control, e.g. passed the ball too far in front of him (especially after the first touch on the ball), thus inviting an opponent tackle in an attempt to win the ball. Defensive tackling duels, where the defender was injured, were also characterized by a low degree of ball control and the exposed player's attention being focused on the ball, and not on the opponent challenging him for ball possession. In incidents occurring during heading duels, player attention was focused on the ball above them and the players seemed to be unaware and unprepared for the duel by the opponent or teammate.

Thus, one common characteristic of all of the three injury mechanisms was poor attention of the exposed player. In just 7% of the incidents and 5% of the injuries occurring during duels, the exposed player attention was focused on the opponent challenging him for ball possession. In contrast, in 90% of the incidents and 95% of the injuries the attention of the exposed player appeared to be focused on the ball in the air or in front of him, and away from the opponent challenging him for ball possession (Figure 7). Another common trend found in this study was that most of the incidents (66%) and injuries (68%) occurred when the exposed player had a low degree of ball control. These two factors seem to be of particular relevance for preventing injuries. This indicates that increasing player awareness of these factors and teaching them to develop avoidance strategies based on increased player attention and better ball control could potentially reduce the risk of injury.

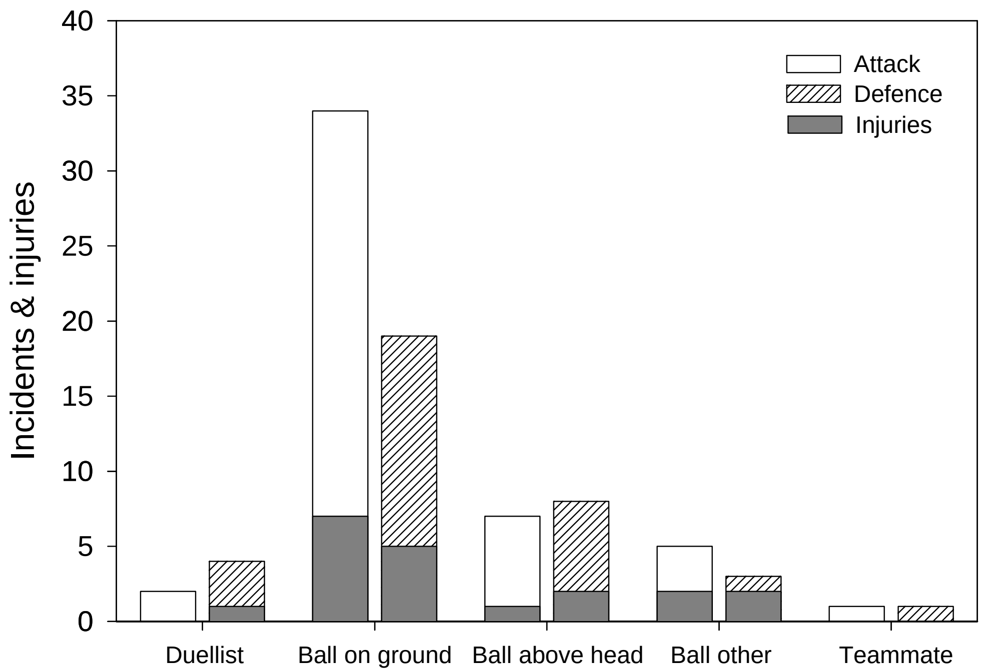

Figure 7. Number of incidents (n=84) and injuries (n=20) during duels, classified according to where the attention of the affected player appeared to be directed (on the primary duelist, on the ball on the field, ball in head height or higher, ball between head height and the field, or a teammate).

Effectiveness of a video-based awareness program

In paper V, no difference was observed in total injury incidence (injuries per 1000 hours) between the intervention and control groups (p=1.0), nor was there a difference between these groups in match (p=0.8) or training incidence (p=0.2) (Table 7). Moreover, no difference was observed between the intervention and control groups in injury distribution related to body part (p=0.5), nor in injury severity (p=0.2). Finally, there was no difference in total injury incidence between the 1999 and 2000 football seasons among the 7 intervention teams (p=0.5) and 6 control teams (p=0.4) that participated in both seasons (see Figure. 2 in paper V).

Table 7. Incidence of injures (injuries/1000 hours) among the teams in the intervention (n=7) and control group (n=8) during the 2000 season.

	Total	Match	Training
Intervention (n=7)	6.6 ± 0.7	25.1 ± 3.2	2.7 ± 0.5
Control (n=8)	6.6 ± 0.7	26.0 ± 3.0	1.9 ± 0.4
Total (n=15)	6.6 ± 0.5	25.6 ± 2.2	2.3 ± 0.3

There are at least three potential explanations for the failure of the program to reduce injury rates in the intervention group. First, it may be that the playing situations we used were not representative. Football is a complicated sport, characterized by short sprints, rapid acceleration or deceleration, turning, jumping, kicking, tackling and many complex actions with or without ball (Wisloff et al. 1998; Bangsbo and Michalsik 2002). Consequently, as shown in paper IV and by Andersen et al. (Andersen et al. 2003), the injury mechanisms in football are also complex. Therefore, it may be more difficult to use a player awareness program to prevent injuries in football, compared to sports with fewer and more specific injury mechanisms, such as ACL injuries in skiing (Ettlinger et al. 1995), and team handball (Myklebust et al. 2003), or ankle sprains in volleyball (Bahr et al. 1997).

Second, the players may have misinterpreted the injury mechanisms from the videos or the prevention strategies they developed were ineffective. In the workshops the players worked together in pairs to analyze the video sequences and they did show a positive attitude. Their written responses were largely the same as the main results from the FIA, with a focus on increased player attention and better quality in the first touch of the ball. These two factors were hypothesized to play a key role to avoid injuries. Attention was believed to be important for the players to be more aware of potential duels with opponents, to avoid collisions with teammates or to know where to send the ball before being tackled by an opponent. The quality of the first touch of the ball depends on several factors, where player technique is probably the most important. Other factors that can influence the quality of the first touch are the quality of the pass that the player receives, the playing situation, field and weather condition. Insufficient ball handling skills and inadequate player attention can be related variables in such way that players with insufficient ball technique also have to focus their attention on receiving the ball and therefore do not have time to assess the playing situation, the location of other players or their actions.

Third, the players could have been unable to change their skills and behavior. When playing elite football, the tempo and requirements are high and players often have only a split second to consider the playing situation. It may have been difficult to change their attitude or behavior in such situations with just one session of the awareness program, especially since improving ball handling skills can take a lot of time. Also, we do not know if the coaches followed up on these injury prevention strategies in training. Possibly an awareness program over a longer period of time, with greater coach involvement could be more effective.

Previous intervention studies that have shown positive effect, are most often based on specific training programs or use of orthosis, but in addition players received information about risk factors, injury mechanisms or some injury prevention strategies (Ekstrand et al. 1983a; Tropp et al. 1985a; Caraffa et al. 1996; Bahr et al. 1997; Heidt, Jr. et al. 2000; Soderman et al. 2000; Junge et al. 2002; Myklebust et al. 2003; Askling et al. 2003). It is not clear, whether the training program or the increased knowledge about injury situation and prevention strategies or both of these factors affected the injury rate in these studies. In the present study no effect was found from the awareness program alone, which indicates that knowledge about risk factors, injury mechanisms and preventive strategies in itself is not sufficient to decrease injury rate. This supports the hypothesis that it was the training programs in the previous studies that were effective to reduce the injury rate, not the increased knowledge and awareness about injury mechanisms, preventive strategies etc.

General discussion

Injury registration and exposure data

The precision of reported incidence rate as well as specific injury types and severity depends on the quality of the injury registration and the recording of exposure data. The injury registration was in all of our studies performed prospectively by the team physical therapists, but because most of the teams have limited resources physical therapists were only present before, during and after matches, and only occasionally during training sessions. This limited training attendance could possibly lead to an underestimation of minor injuries, which caused the players to miss only one or two training sessions. During the 1999 and 2000 studies, the period injuries were registered was limited to the competitive season, so injuries that happened before the season started were not included in the study, even if they prevented the players from participation at the beginning of the season. Injury duration was recorded to the end of the season which can underestimate injury severity late in the season. All of the factors mentioned would contribute to an underestimation of injury rates, which means that the incidences reported probably represent minimum estimates.

Match exposure was obtained from official records, while coaches or their assistants recorded individual training attendance for the players. In a few cases, registration of training exposure was incomplete and exposure had to be estimated based on the training schedule of the teams. This can cause some degree of inaccuracy in training exposure, but the match exposure recording should be highly reliable.

Recording of previous injuries

Previous injuries were registered with a questionnaire. The main limitation of such registration is recall bias, i.e. the players may have forgotten some injuries, or they could not remember the injury site (right or left). This will underestimate previous injuries and decrease the statistical power of previous injuries as a risk factor for new injuries, which means that odds ratio and p-values reported for previous injuries as a risk factor are minimum values.

Different tests performed

The physiological variables were measured using established methods with acceptable reliability, and our impression was that the players were well motivated. When calculating the team average for each test in paper III, teams with less than 10 players tested were excluded from that particular test, because they were not estimated to be a representative part of the whole team. Each test chosen in this study was thought to be valid for their purpose. The intra-rater reliability of the flexibility tests, jumping tests and power tests used in paper II and III was tested in our lab and found to be good. The intra-rater reliability of the flexibility tests used in paper I have been shown to be acceptable by Ekstrand et al. (Ekstrand et al. 1982). The tests for peak O_2 uptake and body composition are well established methods that have been used for years in the physiological laboratory at the Icelandic University. However, at the end of the peak O_2 uptake test, some of the players did not reach the predetermined respiratory exchange ratio of 1.1 and therefore it was decided to use the term peak O_2 uptake rather than maximal O_2 uptake. However, these players were very close to this value, well motivated and seemed to run until volitional exhaustion. It may be that local muscle fatigue in the leg muscles stopped some of the players before they reached their maximum O_2 uptake, or that some players also need more psychological strength to reach their maximum value.

Mechanical stability of ankles and knees were tested manually by one experienced physical therapist, using established methods described by others (Arnheim 1989; Magee 1992). Reliability tests were not performed before testing, but these tests have been standardized and used before in many studies as well as clinically.

Video recordings and Football incident analysis (FIA)

During the 1999 season one physical therapist carefully watched all available matches from the Icelandic elite league and transferred the injury-risk incidents and the events leading up to them to a master tape to further analysis. The analysis was performed by the same physical therapist and a football expert using the FIA, which has shown good intra and inter-rater reliability (Andersen et al. 2003). However, as discussed earlier, only 54% of registered injuries were identified on video. The main reason for this is that during most of these matches just one camera was used, which usually followed the ball. Therefore, injuries occurring away from the ball were usually not taped. Injuries that did not cause the referee to stop the match or where the player did not lay down for at least 15 seconds would also have been overlooked.

Awareness program

The design used was a block-randomized controlled study, where the teams in the intervention group completed an awareness program based on the principle of "guided discovery". This method requires active participation of the players. To stimulate discussion, the players worked in pairs to analyze incidents and develop prevention strategies. Our impression is that they did show positive attitude. This method has been shown to be effective to prevent ACL injuries in skiers (Ettlinger et al. 1995), so it was decided to test it on the more complex injury mechanisms seen in football. To see an effect from this method the players would have to identify the injury mechanisms for at least some of the high-risk situations, and develop an implement effective strategies to prevent injuries. As previously discussed in detail, there may be several explanations why this approach was ineffective in reducing injury risk in this player population.

Statistical power

One of the main limitations in prospective cohort studies on risk factors for injuries is the statistical power. Factors that can affect statistical power are sample size, number of different injuries among the players, strength of true association between risk factors and injury risk and the significance level must not be too low (Murphy et al. 2003; Bahr and Holme 2003). According to Murphy et al. (Murphy et al. 2003), the main limitation of most previous studies on risk factors is the small number of subjects and injuries included in the studies. In paper II, 306 players incurred 206 acute injuries, with hamstring strains (n=31), groin strains (n=22), ankle sprains (n=20) and knee sprains (n=20) as the most usual injury types. According to Bahr and Holme (Bahr and Holme 2003), moderate to strong association between risk factors and injury risk require 30-40 injury cases in a sample of 300 subjects, while small to moderate association requires much more cases. Therefore we could expect a type 2 error when studying specific injury types, i.e. the number of injuries is not large enough to detect weaker relationship between possible risk factors and injury risk.

If multivariate analysis is used to control for interaction and confounding between potential risk factors for injuries, it is important to be able to collect all required information on risk factors from as many of the participants as possible. The players needed to report for testing on two occasions, because O_2 uptake and power tests could not be performed on the same day. Some players did not show up for some of their appointment. The number of players that participated in each of the tests varied between 215 and 257, but only 153 of the players participated in all of the tests. This limits the usefulness of the multivariate tests, especially when examining risk factors for specific injury types with fewer injury cases. The reason why players did not participate in testing is in most cases unknown, a handful were injured during the test period, some declined their invitation to be tested and other did not show up for their appointment. Some of the teams also needed to travel to Reykjavik to be tested, which also can be a reason why some of the players did not show up for tests. Players that participated in different tests were not different from players who did not participate in age, height, weight, level of play or injury rate, but for most of the tests they had significantly higher exposure during matches than those who did not participate. This indicates that we were able to test the most exposed players. Nevertheless, drop out from some of the tests by some of the players therefore limited the usefulness of the multivariate approach.

Candidate risk factors not examined

Risk factor analysis in football is complex and many factors can contribute to injuries. In the present study we had limited time available for testing, because we wanted to perform all tests just before the season started. We had also limited resources so we could not have many players tested at the same time because of lack of test personal. Therefore we were not able to perform all the tests we would have wanted. Tests that were not performed include tests of muscle strength (except leg extension power), neuromuscular control, technique, psychological factors, as well as coaching factors. Also, we were not able to consider the quality of the treatment after injuries or perform an evaluation of rehabilitation before players participated at full tempo during training or match. Other factors we did not measure were reaction time and anatomical alignment.

Because the high incidence of hamstring strains, it would been interesting to test *hamstring strength* and *hamstring/quadriceps strength ratio*, and its possible association to injuries. This was not done for several reasons. Before the study we did not know the injury rate and we did not expect such a high incidence of hamstring strains. With respect to knee joint stabilization during running, it has been suggested that the agonist-antagonist strength relationship for knee extension and flexion may be better described by a functional hamstring/quadriceps ratio, i.e. eccentric hamstring/concentric quadriceps ratio or concentric hamstring/eccentric quadriceps ratio, than when only concentric measurements are compared (Aagaard et al. 1995; Aagaard et al. 1996). Although no studies are found that have examined the mechanism of hamstring strains directly (Bahr and Holme 2003), these injuries are manly thought to occur during maximal sprinting, when resisting knee extension or at foot strike (Jonhagen et al. 1996; Swanson and Caldwell 2000). Therefore, eccentric hamstring strength and the eccentric hamstring versus concentric quadriceps strength ratio are of special interest (Aagaard et al. 1995; Aagaard et al. 1998). To measure eccentric strength at high speed the players must report at least twice familiarization for testing before the final test. This type of movement is new for the players and it is difficult to obtain maximal force at the first time. Unfortunately, it was not feasible to perform such strength tests. It would also have been of interest to test adductor muscle strength in the hip.

Inadequate neuromuscular control can cause functional instability, which is supposed to increase ankle injury risk (Tropp et al. 1984). Studies have also shown a preventive effect of neuromuscular training to prevent ligament sprains in ankles or knees (Tropp et al. 1985a; Caraffa et al. 1996). Because of a general lack of accurate and valid tests, we were not able to test the neuromuscular control.

Player technique can be estimated with different field tests (Rosch et al. 2000). Because of restricted time and personal, we were not able to test player technique before the injury registration started. Although video analysis of injury risk incidents was performed and some technique-related factors were indicated as possible risk factors for high risk incidents and injuries, we do not have data to study possible difference in injury rate between players with good versus poor technique.

Previous studies indicate that *psychological factors* such as life-event stress, a fighting mentality and risk-taking behavior could be risk factors for injuries (Dvorak et al. 2000; Junge 2000; Delaney et al. 2002). This could be studied with psychological questionnaires.

Different *coaching factors* could possibly affect injury risk. The quality of coaching can for example be related to education level, experience and how they cooperate with the medical team, assistant coaches and the players, as well as their ability to explain and even demonstrate technical or tactical aspects.

Some authors indicate that *inadequate rehabilitation* and *too early return to matches and training at high intensity* could be a risk factor for recurrent injuries (Dvorak and Junge 2000; Murphy et al. 2003). Unfortunately, we did not collect data on rehabilitation of the players (how the rehabilitation was performed, how many rehabilitation sessions were performed, the status of rehabilitation when the player started training at full tempo or playing matches). In Iceland a short competitive season and relatively few players in the squad among most of the teams increase the pressure on the players to participate in matches as early as possible after injuries. Since physical therapists mainly were present during matches, and most or all of the rehabilitation occurred in their clinics, it would probably limit their ability to follow up injured players on the field until they were fully rehabilitated. Therefore, it had been of interest to test the players' physical fitness, as well as perform some specific performance tests for the injured body part, to get some information on the rehabilitation status just before they started to play at full tempo.

Long reaction time could be a risk factor in some duel situations in football. One retrospective study on football players found a correlation between long reaction time for light stimulus and previous injuries (Taimela et al. 1990b), while another study did not find such correlation (Junge et al. 2000b).

Anatomical malalignments, such as hyperextended knees or tibial varum, could increase the risk of lower leg or ankle injuries in female football players (Beynnon et al. 2001; Soderman et al. 2001b). However, there is a lack of evidence on this issue. Anatomical malalignment could possibly decrease the ability to absorb a high training load and therefore make them more prone to injuries.

In this project we decided to study only male players at the elite level (from the two highest divisions in Iceland). This was done to have as large a group of players as possible of same gender and similar level of play. Female players have a somewhat different injury pattern compared with male players (Ostenberg and Roos 2000) and possibly the risk factors are different. Naturally, it is important to keep in mind that the results may be different in other player populations, such as players from lower divisions, youth players or female players.

During the present study, *weather conditions* were not registered. Studies are found that indicate more injuries in dry than wet weather, most likely because of its effect on the quality of the playing surface (Orchard et al. 1999; Orchard 2002). Cold and windy weather could also possibly increase the injury rate. In Iceland weather condition change very quickly. Since it is not uncommon that during one training or match the weather condition can change radically, it is nearly impossible to get reliable data to study effect of weather conditions on injury rate in Iceland.

Conclusions

1. The incidence of injures in Icelandic elite male football is high, with hamstring strains as the most frequent injury type, followed by groin strains, ankle and knee sprains. Knee ligament sprains were the most severe injuries.

2. Increased age was found to be a risk factor for injuries in general. For hamstring strains increased age and previous hamstring strains were found to be the main risk factors, and for groin strains previous groin strains and decreased ROM for hip abduction were the main risk factors. For ankle and knee sprains previous sprains on the same side was the only risk factor observed.

3. There was a significant relationship between jumping ability and team success (final league standing). There was also a trend to relationship between leg extension power and team success, as well as increased number of injury days per team and decreased team success.

4. Goalkeepers were taller and heavier than outfield players, more flexible in hip extension and knee flexion, had a higher leg extensor power, lower peak VO_2 and fewer injury days. Less pronounced differences were observed in physical fitness between different player positions among outfield players, except that midfield players were older and had less leg extensor power than strikers, and were not as tall as defenders.

5. 57% of incidents found on video could be classified in three compound injury mechanisms, where player attention and ball control appeared to be of importance: a) Break-down attacks with tackling from the side or the front and with the attention focused on the ball (24%), b) Defensive tackling duels with player attention focused on the ball or with low degree of ball control (20%), c) Heading duels with the attention focused on the ball in the air (13%).

6. No effect was observed in injury incidence from a video-based program designed to improve player awareness of the most common situations leading up to incidents and injuries in football.

Future studies

Although the present study has provided some information on risk factors and injury mechanisms in football, the study has also raised many questions:

- Studies are needed to evaluate more potential risk factors for injuries in football. These studies should be large enough to have sufficient power, and use a multivariate approach to evaluate potential intrinsic and extrinsic risk factors.

- More studies are needed on injury mechanisms of specific injury types, e.g. ankle and knee sprains, hamstring and groin strains and head injuries.

- Research is needed to study the effect of preventive measures against different types of injuries in football.

- Research is also needed to standardize programs for preventive measures in football.

- More studies are needed to study risk factors, injury mechanisms and preventive measures in junior football and among female players.

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