Oslo Sports Trauma Research Center
Norwegian School of Sport Sciences
&
Orthopaedic Center
Division of Neuroscience and Musculoskeletal Medicine
Ullevaal University Hospital

Faculty of Medicine
University of Oslo

Football and injuries
Screening, risk factors and prevention

Anders Hauge Engebretsen

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"Tom Lund dribler av to engelskmenn. Helt ned til... Så blir han felt... blir han felt av grisen Phil Neal. Rampen Phil Neal sparker Tom overende bakfra. PHIL GRIS NEAL!! Begynn å ta igjen, gutter! Begynn å ta igjen! Engelskmennene har ramp både på banen og på tribunen. Tom Lund gikk forbi to engelskmenn. Phil Neal overfalt ham bakfra. For en gris! For en fotballramp Phil Neal er!
Dette skal han ha igjen, gutter. Ta ham ved første anledning."

Bjørge Lillelien, Norge – England 9. september 1981

Summary

Background

Football (soccer) is one of the most popular sports in Norway as well as in the rest of the world, and the injury risk is considerable and high compared to most other team sports. Studies have shown that the majority of football injuries occur in the lower extremities, especially affecting the ankle, knee, hamstrings and groin. Ankle and knee sprains and hamstring and groin strains may leave athletes out of play for several weeks, and in many cases full recovery takes much longer. These common injuries therefore represent a concern.

Aims

The main aims of this thesis were to identify risk factors for the four most common injury types in football, ankle and knee sprains and hamstring and groin strains, screen for players with the highest injury risk and to examine if exercise programs targeting the players with an increased risk of injury could prevent these injuries.

Material and methods

A total player population of 508 players representing 31 teams from Norwegian 1st, 2nd and 3rd division of football for men was used for all studies (Paper I-V). A randomized controlled trial was carried out to prevent injuries (Paper I), while prospective cohort studies (Papers II-V) were carried out focusing on potential ankle (Paper II), knee (Paper III), hamstring (Paper IV) and groin risk factors (Paper V). During the preseason the players filled out a questionnaire and went through testing for potential risk factors for ankle, knee, hamstring and groin injury. Based on information from the questionnaire, the players were divided into a high risk and low risk group. The high risk players were randomized individually into an intervention group, which received equipment and training programs, and a control group (Paper I). The preseason testing made out the foundation for investigating the potential risk factors for injury (Paper II-V).

Main results

During the football season, 505 injuries were reported, sustained by 56% of the players. The total incidence of injuries during the season was 4.7 injuries per 1000 playing hours (95% CI 4.3 to 5.1), 12.1 (95% CI 10.5 to 13.7) for match injuries and 2.7 (95% CI 2.4 to 3.1) for training injuries. The total exposure to match play and training was 108 111 player hours. There were 56 acute ankle injuries affecting 46 legs (43 players), 61 acute knee injuries affecting 57 legs (53 players), 76 hamstring injuries affecting 65 legs (61 players) and 61 groin injuries affecting 55 legs

(51 players) respectively. There was a significantly lower injury risk in the group of players with no previous injuries and normal function scores compared to the other players. However, the introduction of individual specific preventive training programs did not affect the injury risk in this intervention, most likely due to low compliance with the training programs prescribed (Paper I). In the multivariate analyses, number of previous acute ankle injuries (Paper II), previous acute hamstring injury (yes/no) (Paper IV) and previous acute groin injury and weak adductor muscles as determined clinically (Paper V) proved to be significant predictor of new injuries. Regarding risk factors for knee injuries, none of the tested factors were associated with an increased injury risk (Paper III) in the final multivariate analysis.

Conclusions

Risk factors for the most common injuries in football were mapped in the present study. This is an important step towards prevention of injuries, which make out a considerable concern in sports in general and football in particular. High risk players were successfully identified through simple self-report screening. Due to a low compliance with the training programs prescribed, it is impossible to tell if the preventive measures tested in the present study are useful. Preventive interventions must therefore be tested in future randomized controlled trials.

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List of papers

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

I. Engebretsen AH, Myklebust G, Holme I, Engebretsen L, Bahr R. *Prevention of injuries among male football players – a prospective, randomized intervention study targeting players with previous injuries or reduced function.* Am J Sports Med. 2008; 36(6):1052-9.

II. Engebretsen AH, Myklebust G, Holme I, Engebretsen L, Bahr R. *Risk factors for acute ankle injuries among male football players – a prospective cohort study.* Scand J Med Sci Sports. 2009 Jun 23. [Epub ahead of print].

III. Engebretsen AH, Myklebust G, Holme I, Engebretsen L, Bahr R. *Risk factors for acute knee injuries among male football players – a prospective cohort study.* Scand J Med Sci Sports. 2010 Mar 11. [Epub ahead of print].

IV. Engebretsen AH, Myklebust G, Holme I, Engebretsen L, Bahr R. *Risk factors for hamstring injuries among male football players – a prospective cohort study.* Am J Sports Med. 2010 Mar 24. [Epub ahead of print].

V. Engebretsen AH, Myklebust G, Holme I, Engebretsen L, Bahr R. *Risk factors for groin injuries among male football players – a prospective cohort study.* Am J Sports Med. In press, May 2010.

Abbreviations

FIFA	-	Fédération Internationale de Football Association
UEFA	-	Union of European Football Associations
FAOS	-	Foot and Ankle Outcome Score (Roos et al., 2001)
KOOS	-	Knee Osteoarthritis Outcome Score (Roos et al., 1998)
HaOS	-	Hamstring Outcome Score (see appendix to Paper I)
GrOS	-	Groin Outcome Score (see appendix to Paper I)
HR intervention group	-	High-risk intervention group
HR control group	-	High-risk control group
LR control group	-	Low-risk control group
BMI	-	Body mass index
OR	-	Odds ratio
CI	-	Confidence interval
SD	-	Standard deviation
SEM	-	Standard error of the mean

Introduction

Football – the world's and Norway's most popular sport

Football (soccer) is a complex contact sport, combining high demands for physical, physiological, technical, and tactical skills (Inklaar, 1994a; Reilly et al., 2000), and is characterized by short sprints, rapid acceleration or deceleration, turning, jumping, tackling and kicking (Wisløff et al., 1998). The immense joy and excitement that goals, great efforts and victories awaken have made it the world's probably most popular sport, including a total of 270 million licensed players (whereof 240 million male players) - or four per cent of the world's population – in 207 countries registered with the Fédération Internationale de Football Association (FIFA)(FIFA big count, 2007). Approximately 1% of these participate at the professional level (Ekblom, 1986; Dvorak et al., 2000a). In Norway, 7.6% of the total population are registered in the Norwegian Football Association (NFF) (NFF, 2009), with more than 250.000 male players.

Football history

According to FIFA, football as we know it today has developed from at least half a dozen different games played in different cultures (FIFA - The History of Football, 2010). Reports indicate that for thousands of years people have enjoyed kicking a ball about and is by no means to consider as an aberration of the more 'natural' form of playing a ball with the hands. The earliest described form of the game was called Tsu' Chu and stems from the Han Dynasty in China. It dates back to the second and third centuries BC (FIFA - The History of Football, 2010) and was an exercise from a military manual consisting of kicking a leather ball filled with feathers and hair through an opening, measuring only 30-40 cm in width, into a small net fixed onto long bamboo canes. Some 500-600 years later, another form of the game was the Japanese Kemari, which is still played today. In contrast to Tsu' Chu, there is no struggle for possession involved. Standing in a circle, the players had to pass the ball, in a relatively small space, trying not to let it touch the ground. Later, there were several other versions, such as the Greek "Episkyros" and the Roman "Harpastum".

However, the contemporary history began in 1863 in England, when rugby football and association football branched off on their different courses, forming the first governing body of the sport, the Football Association (FA) in England. By 1863, the first basic rules were established. Around 1885, football started to pick up in Norway, probably introduced by sailormen from England. After some failed attempts, a new club, "Idrætsforeningen Lyn", which would persist until today, was founded the 3rd of March, 1896 (LYN, 2010). Together with the two clubs "Grane" and "Spring", they founded the Norwegian Football Federation (NFF) in 1902. The Federation of International Football Associations (FIFA) was founded two years later, in 1904.

The game of football

During recent decades, football has evolved and become faster and more aggressive and is played with higher intensity (Tumilty, 1993). Still, the total distance covered in the highest level football matches is reported to have stayed rather constant, approximately 10-12 km for the average outfielder (Tumilty, 1993; Stølen et al., 2005). Nowadays, individual GPS tracking keeps the spectators updated on every step made. And these steps is not just jogging around; the average intensity is close to the anaerobic threshold, representing 80-90% of maximal heart rate (Stølen et al., 2005).

During the past century the sport has changed substantially. The rules are thoroughly defined in the "Laws of the Game". Outdoor football of today is played by two teams of 11 players each, one goalkeeper and ten outfielders. An official match in senior football consists of two 45-min halves with a 15-min half-time break. The playing fields historically come with natural grass, but artificial turf is getting more and more common, especially here in Norway with unstable weather conditions. The playing field has to be rectangular, i.e. the length needs to be longer than the width. The fields vary in sizes from 90-120 m long (100-110 m in international matches) and 45-90 m in width (64-75 m in international matches).

How to prevent injuries in football

van Mechelen et al (1992) have presented a four-step research model for prevention of injuries in sports. First, the extent of injuries in sports must be mapped. Then, the risk factors and injury mechanisms have to be identified. When these two parts are known to satisfaction, one can start to investigate what can be done to prevent injuries. Finally, in this model the effect of the measures is evaluated by repeating the first step. Alternatively, the effectiveness of these measures can be assessed in a randomized controlled trial (van Mechelen, 1997).

Football – a high risk sport

Unfortunately, injuries are part of the game. Among the most common injuries are sprain and strain injuries which may leave athletes out of play for several weeks, and in many cases full recovery takes much longer. Football injuries therefore constitute a concern for the affected individuals and for the society, and result in large health expenses (Finch & Cassell, 2006). A study from English professional football found the risks associated with minor, moderate, and major acute injuries and osteoarthritis in lower limb joints of footballers to be unacceptably high when evaluated against work based risk criteria used by the Health and Safety Executive (Drawer & Fuller, 2002). Also, compared to other sports, football has been shown to have a high injury risk (Junge et al., 2004b) which results in high injury rates when the above stated popularity of football is taken into consideration. However, to compare injury risk across different occupations, sports, age groups and levels, it is of utmost importance to take differences in the injury definitions used into account.

Definition of injury

Differences in study design and injury definitions make a direct comparison between studies difficult. Several different definitions of what constitutes a sport injury occur in the literature (Inklaar, 1994a; Dvorak & Junge, 2000; Junge & Dvorak, 2000; Wong & Hong, 2005), and many authors have therefore pointed out the need for a consensus in not just injury definitions, but also study design, data collection and procedure (van Mechelen et al., 1992; Inklaar, 1994a; Dvorak & Junge, 2000; Junge & Dvorak, 2000; Ekstrand & Karlsson, 2003; Brooks & Fuller, 2006). With respect to football medicine, this resulted in a methodological consensus statement (Fuller et al., 2006). The consensus suggests that an injury is defined as "*Any physical complaint sustained by a player that results from a football match or football training, irrespective of the need for medical attention or time-loss from football activities*." It refers to injuries causing the player to seek medical attention as "medical-attention" injuries, while injuries that force a player from taking full part in future football training or match play as "time-loss" injuries. Also, injuries occurring during leisure time or other sports are not counted as injuries. Previously, other authors have recorded injuries that caused insurance claims to be submitted or required treatment in a traumatology department or hospital. Obviously, such definitions would exclude less severe and also most overuse injuries. Historically, however, defining injury according to *time loss* has been most widely used when studying the injury characteristics of elite football. This definition requires the player to have missed at least one training session or match (Árnason et al., 1996; Witvrouw et al., 2003; Árnason et al., 2004b), the next training session or match (Ekstrand & Tropp, 1990; Askling et al., 2003; Hägglund et al., 2003; Árnason et al., 2004c; Hägglund et al., 2005; Waldén et al., 2005b; Waldén et al., 2007), the next day (Hawkins & Fuller, 1999; Drawer & Fuller, 2002; Andersen et al., 2003; Andersen et al., 2004a; Andersen et al., 2004c; Árnason et al., 2005) or the next two days (Woods et al., 2002; Woods et al., 2003; Woods et al., 2004). A limitation is that it depends on the frequency of matches and training sessions. In this way, it may introduce bias when comparing different ages and levels of play, such as the elite and sub-elite levels. Also, as some players still elect to play despite discomfort, some overuse injuries may be missed. Hence, the *medical attention injury* definition has been introduced in order to include even less severe injuries than the time-loss definition. However, this definition depends on the level of access to medical personnel and personal factors such as a player's willingness to seek assistance for an injury. The *anatomical tissue injury* definition spans even broader, and includes injuries that occur as a result of playing football regardless of subsequent absence from participation or medical attention. This should enable comparison between different sports. Even so, it depends on how active observers are in finding the injured players and requires an evaluation by a medically qualified co-ordinator. Another potential disadvantage is the risk of including small, irrelevant complaints such as bruises and wounds. Finally, some authors have used a combination of the different injury definitions (Inklaar et al., 1996; Emery et al., 2005).

In conclusion, there are several different definitions of injury used in football medicine research, all with different strengths and limitations. According to the consensus statement (Fuller et al., 2006), *"time loss"* and *"medical attention"* are the definitions suggested for use in order to compare different studies. These two definitions are also the definitions used in the present studies (Papers I-V).

Injury incidence

Table 1 *Injury incidence for the four most common injuries in senior male football*

Reference (author, year)	Population	Injury definition	Injury incidence (Injuries per 1000playing hours)			Ankle injuries		Knee injuries		Hamstring injuries		Groin injuries	
			Overall	Training	Match	Percentage of all acute injuries	Injury incidence (inj/1000h)	Percentage of all acute injuries	Injury incidence (inj/1000h)	Percentage of all injuries	Injury incidence (inj/1000h)	Percentage of all injuries	Injury incidence (inj/1000h)
Ekstrand & Gillquist, 1983a	N=180 amateur (div IV) players in Sweden	Time-loss (≥ 1 day)	-	7.6	16.9	17%	-	20%	-	6.6% 14% (=”Thigh”)	-	2.7% adductors 13% “groin”	-
Nielsen & Yde, 1989	N=123 players in two different levels of play in Denmark (whereof 93 adult males, 30 boys)	Time-loss (≥ 1 day)	-	3.6 (total) 2.3	14.3 (total) 18.5	36%	-	18.3%	-	7.3%	-	5.5% adductor strains 22% (groin injury)	-
Ekstrand & Tropp, 1990	N= 135 players division 1	Time-loss (≥ 1 day)	8.6	4.6	21.8	17-20%	1.7-2.0	-	-	-	-	-	-
	N= 180 players division 2	Time-loss (≥ 1 day)		5.1	18.7								
Inklaar et al., 1996	N=477 male players in two non-professional clubs in the Netherlands	Time-loss/ medical attention/ social or economic effects	15.8[1]	-	-	27.5[1]	-	17.5[1]	-	-	-	-	-
Luthje et al., 1996	N=263 Senior male elite players in Finland	Medical attention	-	1.5	16.6	17%	-	19%	-	22% (=”Thigh”)	-	22% (=”Thigh”)	-
Árnason et al., 1996	N=84 Senior male elite players in Iceland	Time-loss (≥ 1 day)	12.4	5.9	34.8	17%	1.3 overall (4.4/1000 match hours vs 0.1/1000 training hours)	6.5% (knee ligament sprain)	-	18% (of all acute injuries)	1.5	5% (of all acute injuries)	-
Hawkins & Fuller, 1999	N=108 professional players in division I-III in English League clubs	Time-loss (≥ 1 day)	8.5	3.4 (adults only) 3.5 (total)	25.9 (adults only) 27.7 (total)	17% (of all injuries)	-	14% (of all injuries)	-	23% (=”Thigh”)	-	11%	-
Morgan &	N=237	Time-loss	6.2	2.9	35.3	18% (of all injuries)	-	21% (of all injuries)	-	42% of strain injuries were	-	53% of strain injuries were hip	-

Oberlander, 2001	professional players in Major League Soccer	(≥ 1 day)								hamstring strains		adductor strains	
Hawkins et al., 2001	N=91 professional football clubs over two seasons	Time-loss (≥ 2 days)	1.3 injuries per player per season	-	-	17% (of all injuries)	-	17% (of all injuries)	-	15%	-	10%	-
Woods et al., 2003	N=91 professional football clubs over two seasons	Time-loss (≥ 2 days)	-	-	-	11% (of all injuries)	-	-	-	-	-	-	-
Hägglund et al., 2003	N=180 and N=310 elite players in seasons 1982 and 2001 in Sweden	Time-loss (≥ 1 day)	8.3[6] 7.8	4.6[6] 5.2	20.6[6] 25.9	-	-	-	-	-	-	-	-
Junge et al., 2004b	N=12 FIFA tournaments and Olympic Games, 1998-2001	Medical attention	-	-	35[2] (time-loss)	17%[2] (of all injuries)	-	12%[2] (of all injuries)	-	16%[2] (="Thigh")	-	16%[2] (="Thigh")	-
Junge et al., 2004a	N=64 matches of the 2002 FIFA World Cup	Medical attention	-	-	81.0	9% (of all injuries)	-	4% (of all injuries)	-	11% (="Thigh")	-	5%	-
Andersen et al., 2004b; Andersen et al., 2004c	The Norwegian elite 2000 series and Icelandic 1999 and 2000 series	Time-loss (≥ 1 day)	-	-	29.1* 21.5* in Norway 38.4* in Iceland	15%*	4.5 (per 1000 match hours) 3.2 in Norway 6.1 in Iceland	16%*	-	26%* (="Thigh")	-	6%*	-
Árnason et al., 2004b	N=306 players in division I-II	Time-loss (≥ 1 day)	-	2.1*	24.6*	9% (of all injuries)	-	15% (of all injuries)	-	24% (="Thigh")	-	13%	-
Woods et al., 2004	N=91 professional football clubs over two seasons	Time-loss (≥ 2 days)	-	-	-	-	-	-	-	12%	-	-	-
Waldén et al., 2005b	N=11 professional clubs in five European countries	Time-loss (≥ 1 day)	9.4	5.8	30.5	14% (of all injuries)	-	20% (of all injuries)	-	15%	-	12%	
Waldén et al., 2005a	N=310 elite players in Sweden	Time-loss (≥ 1 day) (Study was carried out to compare two different injury definitions. Only time-loss ≥ 1 day is reported here)	7.8	5.2	25.9	10% (of all injuries)	-	16% (of all injuries)	-	23% (="Thigh")	-	16%	-
Hägglund et al., 2005	N=188 players in division I in Sweden and	Time-loss (≥ 1 day)	Denmark Sweden[3]	11.8 6.0	28.2 26.2	13% (of all injuries) 11% & 8%	-	21% (of all injuries) 15% & 17%	-	22% (="Thigh") 23% & 23%		15% 16% & 16%	

	Denmark					(of all injuries)		(of all injuries)		(=”Thigh”)		(=”Thigh”)	
Hägglund et al., 2006	N=262 players in division I in Sweden over two seasons	Time-loss (≥ 1 day)	2001: 7.6	5.1	25.9	7% (of all injuries)	0.5	7% (of all injuries)	0.6	11%	0.8	15%	1.1
			2002: 7.6	5.3	22.7	7% (of all injuries)	0.5	9% (of all injuries)	0.7	13%	1.0	18%	1.3
Hägglund et al., 2007	N=582 Senior amateur players in Sweden	Time-loss (≥ 1 day)	Control group	2.7	12.3	16% (of all injuries)	-	16%[4] (of all injuries)	-	8%	-	8%	-
Waldén et al., 2007	N=16 teams in the men’s senior championship in Portugal 2004 (Youth and female championship not reported)	Time-loss (≥ 1 day)	10.1	2.1	36.0	13% (of all injuries)	-	4% (of all injuries)	-	9% (=”Thigh”)	-	11%	-
Hägglund et al., 2008	N=229 female players and N=239 male players from the Swedish elite league (Onle male numbers reported)	Time-loss (≥ 1 day)	-	4.7	28.1	10% (of all injuries)	0.8	7% (of all injuries)	0.5	12%	1.0	13%	1.0
Engebretsen et al. 2008 (Papers I-V)	N=508 Senior male sub-elite players in Norway	Time-loss (≥ 1 day)	4.7	2.7	12.1	16%	0.5	17%	0.6	15% (14% acute hamstring injuries of all acute injuries)	0.7	12% (6% acute groin injuries of all acute injuries)	0.6
Werner et al., 2009	Between 9 and 17 clubs in seven consecutive seasons in the European professional league	Time-loss (≥ 1 day)	-	-	-	-	-	-	-	-	-	12-16%	1.1 overall (3.5/1000 match hours vs 0.6/1000 training hours)
Petersen et al., 2009	N=374 elite footballers in Denmark	Physical complaint (irrespective of medical attention/time-loss)	-	-	-	-	-	-	-	-	0.34 overall (1.82/1000 match hours vs 0.12/1000 training hours)	-	-
Ekstrand et al., 2009	N=23 first team squads (selected by UEFA as belonging to the 50 best European teams from 2001-2008)	Time-loss (≥ 1 day)	8.0	4.1	27.5	14% (of all injuries)	-	18% (of all injuries)	-	23% (=”Thigh”)	-	14%	-
Hägglund et al., 2009	12 European Championships from 2006 to 2008	Time-loss (≥ 1 day)	10.4	2.8	41.6	19%[5] (of all injuries)	-	16%[5] (of all injuries)	-	21%[5] (=”Thigh”)	-	13%[5]	-

Dupont et al., 2010	(Only Men's Euro 2008 reported) N=32 professional footballers in a top-level team participating in the UEFA Champions League	Time-loss (≥ 1 day)	-	3.7	48.7	13% (of all injuries)	-	17% (of all injuries)	-	28% (="Thigh")	-	14%	-
Bjørneboe J et al., 2010	N=14 professional teams in the Norwegian elite series	Time-loss (≥ 1 day)	4.1*	1.8*	17.1*	18%	0.7	18%	0.7	11%* (of all acute injuries) (23% "thigh")	0.5*	8%* (of all acute injuries)	0.3*

* Only traumatic injuries reported

[1] Only ≥ 19 years reported

[2] Overall injury incidence for all tournaments, including youth and female players

[3] Numbers for Sweden reported for spring and Autumn season

[4] All injuries to the knee region

[5] Youth and female tournaments included

[6] Corrected numbers from (Ekstrand & Tropp, 1990)

Injury incidence is a measure of injury risk corrected for exposure, and should preferably be expressed as the number of injuries per 1000 participation hours (van Mechelen et al., 1992). The incidence of injuries among adult male football players on the elite level has been estimated to range between 25 and 35 per 1000 game hours (Árnason et al., 1996; Hawkins & Fuller, 1999; Junge et al., 2004b; Waldén et al., 2005b). Thus, the injury risk is considerable and high compared with most other team sports (Junge et al., 2004b). Studies from professional leagues in Europe (Norway, Sweden, Iceland, Britain, Fédération Internationale de Football Association [FIFA], and Union of European Football Associations [UEFA]) agree that injuries to the lower extremities constitute the biggest problem (Árnason et al., 1996; Hawkins & Fuller, 1999; Junge et al., 2004b; Andersen et al., 2004c; Waldén et al., 2005a; Waldén et al., 2005b). The four dominating injury types in football are sprains to the ankle and knee and strains of the hamstring and groin. Together, these account for approximately 60-80% of all reported injuries (Hägglund et al., 2005; Waldén et al., 2005b; Hägglund et al., 2009; Ekstrand et al., 2009; Dupont et al., 2010) (Table 1). The incidence in senior male football for ankle injuries alone ranges from 0.5 to 2.0 injuries per 1000 playing hours (Ekstrand & Tropp, 1990; Árnason et al., 1996; Hägglund et al., 2006; Bjørneboe J et al., 2010), accounting for 7% to 20% of all injuries (Ekstrand & Gillquist, 1983a; Ekstrand & Tropp, 1990; Árnason et al., 1996; Hawkins & Fuller, 1999; Hawkins et al., 2001; Morgan & Oberlander, 2001; Woods et al., 2003; Andersen et al., 2004b; Árnason et al., 2004b; Hägglund et al., 2005; Waldén et al., 2005a; Waldén et al., 2005b; Hägglund et al., 2006; Hägglund et al., 2009; Ekstrand et al., 2009; Bjørneboe J et al., 2010; Dupont et al., 2010). The incidence for knee injuries ranges from 0.5 to 0.7 injuries per 1000 playing hours (Hägglund et al., 2006; Hägglund et al., 2008; Bjørneboe J et al., 2010), and knee injuries account for 7% to 21% of all injuries (Ekstrand & Gillquist, 1983a; Hawkins & Fuller, 1999; Hawkins et al., 2001; Morgan & Oberlander, 2001; Junge & Dvorak, 2004; Árnason et al., 2004b; Hägglund et al., 2005; Waldén et al., 2005a; Waldén et al., 2005b; Hägglund et al., 2006; Ekstrand et al., 2009; Bjørneboe J et al., 2010; Dupont et al., 2010). Strain injuries of the hamstrings, with an injury incidence of 0.8 to 1.5 injuries per 1000 playing hours (Árnason et al., 1996; Hägglund et al., 2006), account for 11% to 15% of all injuries in football (Hawkins et al., 2001; Woods et al., 2004; Waldén et al., 2005b; Hägglund et al., 2006), while the injury incidence for groin strains is reported to be 1.1-1.3 injuries per 1000 playing hours (Hägglund et al., 2006; Werner et al., 2009), and groin injuries account for 10% to 18% of all injuries in senior male football (Ekstrand & Gillquist, 1983b; Hawkins & Fuller, 1999; Hawkins et al., 2001; Árnason et al., 2004b; Hägglund et al., 2005; Waldén et al., 2005a; Waldén et al., 2005b; Hägglund et al., 2006; Hägglund et al., 2008; Werner et al., 2009; Ekstrand et al., 2009; Dupont et al., 2010).

While most of the epidemiology from football is based on the elite level, little is known about the injury incidence on the sub-elite levels among adults. However, there are a few studies from lower levels amateur football which have indicated that the injury incidence may be lower (Ekstrand et al., 1983b; Hägglund et al., 2007).

Consequently, there is a need for more studies to map the injury risk at sub-elite levels of football. This will be addressed in Paper I, and incidences of ankle, knee, hamstring and groin injuries will be reported in Papers II-V. However, as documented above, ankle, knee, hamstring and groin injuries constitute a major concern in football and efforts to prevent these injuries are needed. This issue will be addressed in Paper I.

Football from the 1980s until today

Football has evolved in professionalism during the last decades and become faster and with higher intensity (Tumilty, 1993). Each player has less time until challenged by an opponent, and the margin between victory and defeat is even smaller than before. The best teams continue to increase their physical capacities compared to values reported 30 years ago (Stølen et al., 2005). Accordingly, it may be expected that injury risk has increased correspondingly. As stated above, differences in injury definition make comparisons challenging. Still, as can be seen from table 1, there is no obvious trend towards an increasing injury incidence during the last decades. However, there seems to be a trend indicating an increased proportion of strain injuries, predominantly to the hamstring and groin, while the frequency of ankle and knee injuries has remained constant. Studies from the 1980s and early 1990s found ankle and knee sprains to be the most frequent injuries, accounting for 17-36% (ankle) and 18-20% (knee) of all acute injuries (Ekstrand & Gillquist, 1983a; Nielsen & Yde, 1989; Ekstrand & Tropp, 1990). Hamstring and groin injuries accounted for 6.6-7.3% ("thigh injuries") and 2.7-5.5% of all injuries in the same studies (Ekstrand & Gillquist, 1983a; Nielsen & Yde, 1989). Also, Ekstrand and Gillquist reported strains of the quadriceps muscles to be more frequent than hamstring and hip adductor muscles (Ekstrand & Gillquist, 1982). In contrast, more recent studies have found ankle and knee injuries to account for 15-18% (Andersen et al., 2004b; Andersen et al., 2004c; Bjørneboe J et al., 2010) and 16-18% (Andersen et al., 2004b; Andersen et al., 2004c; Bjørneboe J et al., 2010) of all acute injuries respectively, while hamstring and groin injuries account for 11-15% (Woods et al., 2004; Waldén et al., 2005b; Hägglund et al., 2006) and 12-18% (Árnason et al., 2004b; Hägglund et al., 2005; Waldén et al., 2005a; Waldén et al., 2005b; Hägglund et al., 2006; Werner et al., 2009; Ekstrand et al., 2009; Dupont et al., 2010) of all injuries, as shown in table 1.

This trend towards a shift in frequency from joint injuries to strain injuries is, however, not by any means strong. If there really is a true change from joint to strain injuries, it might be explained by the early introduction of good preventive regimens for ankle and knee injuries (Ekstrand et al., 1983a; Tropp et al., 1985; Surve et al., 1994; Caraffa et al., 1996), and that professionalism in football has ensured the implementation of these measures in daily training by teams striving for success (Árnason et al., 2004a). In contrast, at the same time, the same teams have focused on stretching to prevent strains, a method which nowadays is left with less credibility in the literature (Herbert & Gabriel, 2002; Thacker et al., 2004; Hart, 2005). Other strain-preventive exercises have been introduced later (Askling et al., 2003; Árnason et al., 2008).

Multifactorial etiology model

Understanding the risk factors for injuries is an important foundation for the prevention of injuries. Injury causation is complex and models have therefore been developed to take into account the multicausal etiology and chain of events that lead to injury (Figure 1) (Bahr & Krosshaug, 2005). Traditionally, risk factors have been divided into two main categories; intrinsic athlete related factors and extrinsic environmental risk factors (van Mechelen et al., 1992). Intrinsic risk factors can be further classified as physical (such as height, weight, BMI, age, gender, previous injuries, level of play, flexibility, joint instability, anatomical malalignment, muscle strength, aerobic fitness, functional performance) (Taimela et al., 1990; Inklaar, 1994b; Engström & Renström, 1998; Östenberg & Roos, 2000; Dvorak et al., 2000b; Gissane et al., 2001) and psychological (such as life-event stress, fighting mentality and risk-taking behavior) (Taimela et al., 1990; Dvorak et al., 2000b). Extrinsic factors may be the playing surface, player exposure, playing position, time in match, equipment (shoes, shin guards, use of tape/orthosis), coaching-related factors (quality, training load), rules and foul play (Taimela et al., 1990; Inklaar, 1994b; Engström & Renström, 1998; Gissane et al., 2001; Dvorak, 2009). The intrinsic and extrinsic risk factors contribute towards athlete susceptibility to injuries, but are usually distant from the time of injury and rarely sufficient as a cause of injury alone.

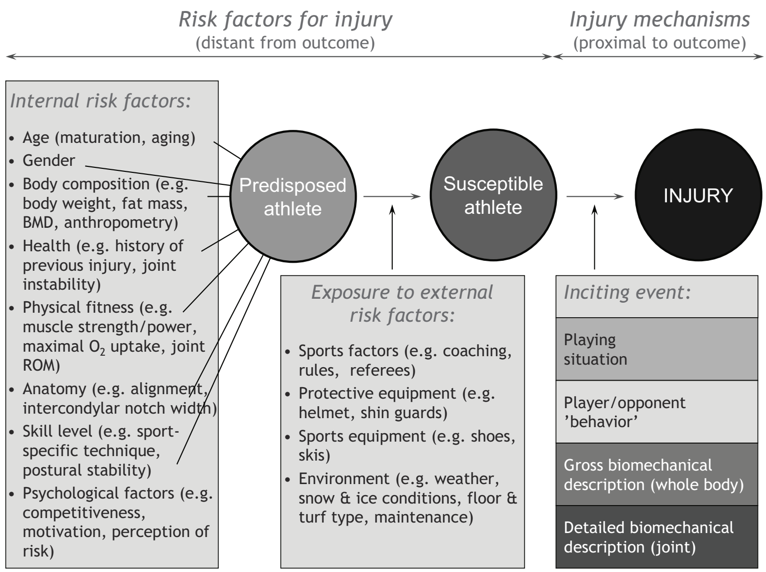

Figure 1. *A multicausal etiology model illustrating the interaction of intrinsic and extrinsic risk factors and the inciting event leading to injury (Bahr & Krosshaug, 2005).*

The classification put forward by Meeuwisse et al (1994) has later been modified by Bahr & Krosshaug (2005) to underline the importance of understanding the inciting event. This way, possible interaction (when two factors work together to produce a risk which is greater or lesser than expected) and confounding (when an association between two variables of interest could be due to the effects of a third variable) are taken into account (Meeuwisse, 1994). As described by Bahr & Holme (2003), there are three main study designs available to study risk factors for sports injuries; case-control studies, cohort studies and intervention studies (preferably done as a randomised controlled trial). Of these, the latter two are preferred, and although randomized controlled trials can provide the strongest evidence to evaluate cause-effect relationships and is the preferred method for testing different preventive measures, they are limited to risk factors that can be modified and are usually used to assess the effect of only one factor at the time. A cohort study design, with the main disadvantage being the size of the study required, was therefore the method chosen for risk factor analyses of ankle (Paper II), knee (Paper III), hamstring (Paper IV) and groin (Paper V) injuries. The risk factor studies (Papers II-V) in this thesis focus on intrinsic physical risk factors. Also, as injuries mainly result from a complex interaction of multiple risk factors and events, multivariate statistical analyses should be used for risk factor studies (Bahr & Holme, 2003).

Risk factors for injuries

Risk factors, whether intrinsic or extrinsic, are either modifiable or nonmodifiable. Nonmodifiable factors cannot be altered, but may still affect the relationship between modifiable risk factors and injury (Meeuwisse, 1991). They can even be used to target intervention programs towards individuals at greater risk.

Risk factors for ankle sprains

Several authors have found previous ankle injury to be a significant risk factor for new injuries. This seems to be a consistent finding, especially when rehabilitation is inadequate, both among senior male soccer players (Ekstrand & Gillquist, 1983a; Tropp et al., 1985; Kofotolis et al., 2007) and in male athletes in other sports (Bahr & Bahr, 1997; McKay et al., 2001; Tyler et al., 2006; McGuine & Keene, 2006; McHugh et al., 2006). In contrast, Trojian & McKeag (2006) in a study among 230 senior male and female athletes from high school and college in American football, soccer and volleyball in the US, did not find a history of a previous injury to be significantly associated with increased injury risk. One has to bear in mind that the above mentioned studies have only included univariate analyses, which is a definite weakness of such studies. However, a multivariate analysis from the two highest divisions of play in male Icelandic football found that players with a history of previous ankle injury had a more than five times higher risk of sustaining a new ankle sprain (Árnason et al., 2004b). Another multivariate risk factor study identified previous injury as a risk factor for the other main injuries in football (knee, hamstring and groin) in Swedish elite male football, but did not succeed in doing so for the ankle (Hägglund et al., 2006). Even so, the authors did conclude that there was a tendency towards an increased risk for ankle sprain in the previously injured leg and a decrease in risk for ankle sprain with increasing age, but none of the variables reached statistical significance.

Amongst other potential risk factors for ankle injuries in male football (see table 2) are clinical instability (Ekstrand & Gillquist, 1983b) and single leg balance test (Trojian & McKeag, 2006). It has also been suggested that there is a greater risk of injury towards the end of a game and that ankle injuries most often occur during the first 2 months of the season (Kofotolis et al., 2007).

Several other potential risk factors have been tested and suggested as possible predictors of increased risk among female players or among male athletes in other sports. These include slow reaction time (Taimela et al., 1990; Árnason et al., 2004b), personality factors (Taerk, 1977; Lysens et al., 1989; Taimela et al., 1990; Junge et al., 2000; Árnason et al., 2004b), age (Backous et al., 1988; Lindenfeld et al., 1994; Östenberg & Roos, 2000), general joint laxity (Baumhauer et al., 1995; Östenberg & Roos, 2000; Beynnon et al., 2001), ankle joint laxity (Beynnon et al., 2001) and balance tests (Trojian & McKeag, 2006). Regarding body size measures such as height, weight and body mass index (BMI), the literature is also inconclusive (Backous et al., 1988; Baumhauer et al., 1995; Beynnon et al., 2001; Tyler et al., 2006). Later, after the start of the present study, a systematic review of postural control and lateral ankle instability (McKeon & Hertel, 2008) has concluded that poor postural control is associated with increased risk of ankle injury.

In a large systematic review on epidemiological studies on sports injury from 1977-2005, Fong et al (2007) report that football is among the sports with the highest ankle injury incidence. Consequently, they recommend that ankle sprain prevention programs should be implemented in these sports. Accordingly, some of the above mentioned risk factors have been tested further in intervention studies among senior male football players. Balance training (Tropp et al., 1985) and the use of orthoses (Tropp et al., 1985; Surve et al., 1994) have resulted in significantly fewer ankle sprains, indicating that reduced neuromuscular control may be an important risk factor for ankle injuries.

Table 2. *Studies on risk factors for ankle injuries in senior male football*

Reference (author, year)	Population	Study design	Injury definition	Univariate / Multivariate	Outcome measure	Risk factors
Ekstrand & Gillquist 1983a	N=180 Senior male amateur players in Sweden	Prospective cohort study	Time-loss (≥ 1 day)	Univariate	Ankle sprain	Previous ankle injury Clinical instability
Tropp et al. 1985	N=439 Senior male amateur players in Sweden, division VI	Randomized controlled trial	Time-loss (≥ 1 day)	-	Ankle injury	Previous ankle injury
Surve et al. 1994	N=629 Senior male players in South-Africa Divisions 1-4	Randomized controlled trial	Time-loss (≥ 1 day)	-	Ankle injury	Previous ankle injury
Árnason et al. 2004b	N= 306 Senior male players from the two highest divisions in Iceland	Prospective cohort study	Time-loss (≥ 1 day)	Multivariate	Ankle injury	Previous ankle injury
Trojian & McKeag 2006	N=230 Senior male and female athletes from high school and college in American football, soccer and volleyball in the U.S.A.	Prospective cohort study	Time-loss (caused the player to miss the rest of practice or competition, or miss the next practice or competition)	Univariate	Ankle injury	Single leg balance test Previous injury not associated with increased injury risk
Hägglund et al 2006	N=263 and N=262 elite male players in two consecutive seasons in Sweden	Prospective cohort study	Time-loss (≥ 1 day)	Multivariate	Ankle injury	No significant risk factors for ankle injury in the multivariate analysis (Previous injury included)
Kofotolis et al. 2007	N=312 Senior male amateur players	Descriptive epidemiology study	Time-loss (≥ 1 day)	Multivariate	Ankle injury	Previous ankle injury Implied that risk of injury is higher toward the end of a game and that ankle injuries most often occur during the first 2 months of the season

Risk factors for knee sprains

A history of previous knee injuries seems to be the most important risk factor for new injuries, both in male football (see table 3) (Ekstrand & Gillquist, 1983a; Árnason et al., 2004b; Hägglund et al., 2006) and among male athletes in other sports (Taunton et al., 2003; Meeuwisse et al., 2003; Yung et al., 2007), especially when rehabilitation is inadequate (Árnason et al., 2004b; Hägglund et al., 2006). Árnason et al. (2004b) found previous knee injury to be the only significant risk factor for a new injury to the same knee in a large cohort study investigating several risk factors for football injuries. In the same study, increased valgus laxity was associated with a history of previous injury. After the start of the present study, previous injury was the only risk factor identified in a recent study from female youth football (Steffen et al., 2008a).

Studies from different sports, age groups or among female athletes have suggested other potential risk factors, but with limited documentation for senior male players. These include gender (Lindenfeld et al., 1994; Ahmad et al., 2006; McLean et al., 2007), age (Backous et al., 1988; Lindenfeld et al., 1994; Östenberg & Roos, 2000), slow reaction time (Taimela et al., 1990), personality factors (Taerk, 1977; Lysens et al., 1989; Taimela et al., 1990; Junge et al., 2000), disobeying fair play (Roberts et al., 1996; Peterson et al., 2000), playing position (Lindenfeld et al., 1994), quadriceps-to-hamstring strength ratio (Ahmad et al., 2006), landing technique (Hass et al., 2005; McLean et al., 2007), fatigue (McLean et al., 2007), neuromuscular control of the knee (Hewett et al., 2005) or trunk (Zazulak et al., 2007), history of low back pain (Zazulak et al., 2007) and general joint laxity (Baumhauer et al., 1995; Östenberg & Roos, 2000; Beynnon et al., 2001; Myer et al., 2008).

Intervention studies have shown that neuromuscular training may prevent knee sprains (Caraffa et al., 1996), indicating that reduced neuromuscular control may be an important risk factor for knee injuries. However, the evidence among adult male players is limited, as most studies have been carried out in other sports or among female or younger athletes (Myklebust et al., 2003; Mandelbaum et al., 2005; Olsen et al., 2005).

Table 3. *Studies on risk factors for knee injuries in senior male football*

Reference (author, year)	Population	Study design	Injury definition	Univariate / Multivariate	Outcome measure	Risk factors
Ekstrand & Guillquist 1983a	N=180 Senior male amateur players in Sweden	Prospective cohort study	Time-loss (≥ 1 day)	Univariate	Knee ligament sprains	Previous knee injury
Árnason et al. 2004b	N=306 Senior male players from the two highest divisions in Iceland	Prospective cohort study	Time-loss (≥ 1 day)	Univariate	Knee ligament injury	Previous knee injury (Especially important when rehabilitation is inadequate) (Only risk factors with p>0.20; hence, no multivariate analysis performed)
Hägglund et al. 2006	N=263 and N=262 elite male players in two consecutive seasons in Sweden	Prospective cohort study	Time-loss (≥ 1 day)	Multivariate	Knee joint trauma	Previous knee injury (Especially important when rehabilitation is inadequate)
Waldén et al. 2006	N=310 elite male players in Sweden	Prospective cohort study	Time-loss (≥ 1 day)	Univariate	Knee injury	Previous ACL injury

Risk factors for hamstring strains

The high incidence of injuries of the hamstring muscle group may partly be explained by the fact that this muscle group functions over two joints (Devlin, 2000; Hawkins et al., 2001; Orchard & Seward, 2002) and is therefore subject to stretch at more than one point (Devlin, 2000; Orchard & Seward, 2002). Also, the greater proportion of fast-twitch fibres in the hamstring muscles compared with other thigh and leg muscles means that they are capable of high force production (Hawkins et al., 2001). Following this chain of thought, a domination of fast twitch (type II) fibres would put a player at increased risk. Interestingly, therefore, Woods et al. (2004) in a large study in English professional football found that players with a black ethnic origin were at increased risk of sustaining hamstring strains compared to white players. No other studies in senior male football have looked into this, but Verrall et al., (2001) in a study from Australian rules football, found players of aboriginal descent to be at increased injury risk. They argue that this could be due to a greater proportion of type II fibres which may predispose them to injury (Verrall et al., 2001). However, the more common occurrence of anteriorally tilted pelvis in players of black origin is also a possible explanation (Brockett et al., 2001). Because ethnic origin was not recorded in the present study, this issue will not be further addressed, but an indirect measure of type II fibres was attained through the sprint and counter movement jump tests (papers III-V).

Indications of important risk factors may arise by examining injury mechanisms. In the study from English professional football, two-thirds of hamstring strains occurred in matches (Woods et al., 2004). Also, a strikingly high proportion of injuries occur during running, and hamstring strains were mostly sustained at the end of matches and training sessions. Furthermore, this is supported by studies suggesting fatigue as a risk factor for hamstring injuries (Worrell, 1994; Kujala et al., 1997; Greig, 2008). Also, a study found a significant reduction in peak eccentric knee flexor torque at high speeds due to passive players remaining seated throughout the halftime interval (Greig, 2008). Because insufficient warm-up is a potential risk factor for hamstring strains (Worrell, 1994; Kujala et al., 1997), it is suggested that re-warming strategies during the halftime interval should be considered, in order to reduce the negative influence of the passive halftime interval (Lovell et al., 2007; Greig, 2008).

The recurrence rate for hamstring strains in football is high (12%) (Woods et al., 2004). The rationale for the high rate of recurrent strain injuries is not fully known, but may be the result of scar tissue formation or other structural changes (Noonan & Garrett, Jr., 1992; Jarvinen et al., 2000) or that full function has not been restored. It is suggested that the shorter optimum of previously injured muscles makes them more prone to damage from eccentric exercise than uninjured muscles (Brockett et al., 2004). The shorter optimum may reflect the muscle's preinjury state or be a consequence of the healing process. Frequently, injuries occur due to too early return to play and incomplete rehabilitation (Croisier et al., 2002; Croisier, 2004). Also, strength deficits or imbalances have been suggested to increase hamstring injury risk (Croisier et al., 2008), although the relationship between advanced isokinetic testing and injury risk is not fully resolved (Bennell et al., 1998).

Given the high recurrence rate for hamstring strains, it is not surprising that previous hamstring injury, especially when rehabilitation is inadequate, is the best documented risk factor for hamstring strains in football (Árnason et al., 2004b) and other sports (Bennell et al., 1998; Verrall et al., 2001; Gabbe et al., 2006). Another study among senior male footballers, carried out after start of the present study, has also shown this association (Hägglund et al., 2006). Also, age has been shown to be a risk factor in Australian rules football (Orchard, 2001; Gabbe et al., 2006) and in football (Árnason et al., 2004b), even independent of history of previous injury (Árnason et al., 2004b). Studies have implied that low hamstring strength (Orchard et al., 1997; Croisier et al., 2002) and muscle imbalances (Worrell, 1994; Orchard et al., 1997; Kujala et al., 1997) may leave players at risk, and a study from American football examining two different rehabilitation programs after acute hamstring strain demonstrated that players who followed an isokinetic strength training program had a significant reduction in risk of reinjury (Heiser et al., 1984). Another study had shown that another eccentric exercise, “Nordic Hamstring lowers”, was useful in injury prevention (Askling et al., 2003). Also, based on a randomized training study among 21 sub-elite and amateur players in Norway (Mjølsnes et al., 2004), the authors suggested that poor eccentric strength may be a risk factor. However, this study did not include any injury data. After the start of the present study, a study among male footballers has shown an injury preventive effect of strength training through systematic use of Nordic Hamstring lowers (Árnason et al., 2008). A listing of risk factors for hamstring strains in senior, male football can be found in table 4.

Among other potential risk factors mentioned in the literature, reduced flexibility has been suggested as a risk factor for hamstring strains (Witvrouw et al., 2003), which is in concordance with studies from other sports as well (Worrell, 1994; Kujala et al., 1997; Hartig & Henderson, 1999). It has also been shown that soccer players were less flexible than a control group (Ekstrand & Gillquist, 1982) and that soccer players often do not pay sufficient attention to stretching exercises (Ekstrand et al., 1983b; Inklaar, 1994b; Árnason et al., 1996; Hawkins & Fuller, 1998). Studies from other sports and populations have suggested other factors that may predispose for hamstring strain injuries; neural tension (Turl & George, 1998) and dyssynergic contraction of muscle groups (Agre, 1985). However, the largest study to date in male football examining the effect of flexibility training did not detect a preventive effect (Árnason et al., 2008).

Table 4. *Studies on risk factors for hamstring injuries in senior male football*

Reference (author, year)	Population	Study design	Injury definition	Univariate / Multivariate	Outcome measure	Risk factors
Witvrouw et al. 2003	N=146 professional players in Belgium	Prospective cohort study	Time-loss (≥ 1 day)	Univariate	Hamstring muscle group injury	Decreased flexibility of the hamstring muscles
Árnason et al. 2004b	N= 306 players from the two highest divisions in Iceland	Prospective cohort study	Time-loss (≥ 1 day)	Multivariate	Hamstring strain	-Age -Previous hamstring strain
Woods et al 2004	N=91 professional English football clubs over two seasons	Prospective cohort study	Time-loss (≥ 2 days)	Univariate	Hamstring strain	-Younger players at lower risk -Players with black ethnic origin at increased risk compared to white players -Player position; goalkeepers at decreased risk compared to outfielders -Play at the highest level
Hägglund et al. 2006	N=263 and N=262 elite players in two consecutive seasons in Sweden	Prospective cohort study	Time-loss (≥ 1 day)	Multivariate	Hamstring injury	Previous hamstring injury Increasing age

Risk factors for groin strains

A listing of risk factors for groin injuries in senior male football can be seen in table 5. As for ankle, knee and hamstring injuries, previous injury, especially when rehabilitation is inadequate, places an athlete at increased risk of suffering a new groin strain injury (Árnason et al., 2004b; Hägglund et al., 2006). Age has also been suggested as risk factor for groin injuries (Árnason et al., 2004b) in football, while age and experience have been suggested in elite ice hockey (Emery & Meeuwisse, 2001).

Among other potential risk factors, a study among 146 professional male players in Belgian football did not find any risk factors for adductor muscle injury when examining height, weight, training/game time or muscle flexibility (Witvrouw et al., 2003). Yet, studies from different sports have suggested strength imbalances between the propulsive muscles and the stabilizing muscles of the hip and pelvis (Garrett, Jr. et al., 1987) and between the synergistic abductors and adductors as risk factors for groin injuries (Maffey & Emery, 2007). Also, delayed contraction of the transversus abdominis, as a measure of reduced core stability, has been suggested (Cowan et al., 2004). No previous studies (Tyler et al., 2001; Árnason et al., 2004b) have identified adductor length as a risk factor for groin injury in soccer, and stretching programs do not seem to influence injury risk (Thacker et al., 2004). As stated above, the study from Belgian elite soccer found no predictive value of adductor flexibility measurements (Witvrouw et al., 2003). Still, Árnason et al. (2004b) found decreased range of motion for hip abduction to be a significant risk factor for groin injuries.

In studies from other sports, other potential risk factors are mentioned, but the results and study groups differ widely. These include high level of play (Inklaar et al., 1996), age (Emery & Meeuwisse, 2001), core stability (Leetun et al., 2004; Cowan et al., 2004), decreased range of motion in hip abduction (Árnason et al., 2004b) and weak adductor muscles and abnormal muscle ratios (Emery, 1999; Tyler et al., 2001).

Table 5. *Studies on risk factors for groin injuries in senior male football*

Reference (author, year)	Population	Study design	Injury definition	Univariate / Multivariate	Outcome measure	Risk factors
Ekstrand & Guillquist 1983a	N=180 amateur players in Sweden	Prospective cohort study	Time-loss (≥ 1 day)	Univariate	Groin injury	Preseason hip abduction range of motion was decreased in soccer players who subsequently sustained groin strains
Witvrouw et al. 2003	N=146 professional players in Belgium	Prospective cohort study	Time-loss (≥ 1 day)	Univariate	Adductor muscle injury	No significant difference between the injured and uninjured groups in height, weigth, training/game time or muscle flexibility for adductors
Árnason et al. 2004b	N= 306 players from the two highest divisions in Iceland	Prospective cohort study	Time-loss (≥ 1 day)	Multivariate	Groin strain	-Previous groin strain -Decreased range of motion in hip abduction (Univariate analyses also found increasing age to be a potential risk factor)
Hägglund et al. 2006	N=263 and N=262 elite players in two consecutive seasons in Sweden	Prospective cohort study	Time-loss (≥ 1 day)	Univariate	Groin injury	Previous groin injury (Only risk factors with p<0.20; hence, no multivariate analysis performed)
Werner et al. 2009	Between 9 and 17 clubs in seven consecutive seasons in the European professional league	Prospective cohort study	Time-loss (≥ 1 day)	Univariate	Groin injury	Carried out to investigate incidence, pattern and severity of groin injuries. Found re-injuries to account for 15% of all registered injuries.
Hölmich et al. 2009	N=977 players			Univariate	Groin injury	-Previous groin injury (doubles the risk of developing a new groin injury) -Playing at a higher level (almost triples the risk of developing a groin injury)

General considerations on risk factors

Understanding the etiology of risk factors and mechanisms of injuries in football is an important foundation for the prevention of injuries (Meeuwisse, 1994). As described above, previous injury is the most consistent risk factor for new injury in all four body parts; ankle, knee, hamstrings and groin. Unfortunately, very little is known about risk factors in subelite level male footballers. Also, very few other potential risk factors have been studied in depth and there is a need for larger cohort studies mapping risk factors for the four most common injuries in football in a multivariate model. A range of previously suggested risk factors and also other potential risk factors for ankle, knee, hamstring and groin injuries among male football players were therefore studied in Papers II-V.

Screening

Screening, in medicine, is a strategy used in a population to detect disease in individuals without signs or symptoms of that disease. The intention is to identify disease early, thus enabling earlier intervention and management in the hope of reducing mortality and suffering. Although screening may lead to an earlier diagnosis, not all screening tests have been shown to benefit the person being screened; overdiagnosis, misdiagnosis, and creating a false sense of security are some potential adverse effects of screening. For these reasons, a test used in a screening program, especially for a disease with low incidence, must have good specificity in addition to acceptable sensitivity.

In sports medicine, screening tests may be used to assess susceptibility of sustaining injury, in order to target preventive interventions to the players in the most need of such measures (Dvorak et al., 2000b). The International Olympic Comittee (IOC) has recently stated that one priority is to protect the health of the athlete and that a preparticipation examination or periodic health evaluation to screen for injuries is an important enterprise in that matter (Ljungqvist et al., 2009). Implementing the preventive measures among the players in the greatest need of them may be important, partly because ensuring good compliance with specific exercise programs has been shown to be a challenge (Myklebust et al., 2003). Also, focusing mostly on one body region for a player with high risk of injury to that specific region might be more effective than a general preventive program.

Research on risk factors on the elite levels of football, where financial resources are much larger compared to amateur levels, may influence the choice of potential predictors tested. However, elite players only constitute a small portion of all football players, and advanced resources for screening tests are not available for the majority of players. Therefore, there is a need for investigation about whether simple screening tests, which are easy to do and do not require advanced equipment, can be used to identify individuals at risk. In this way, teams and players with no medical staff would be able to test themselves in the pre-season to find out whether they have an increased risk of injuries. Whether simple screening methods (e.g. questionnaires) are as effective as more advanced methods (e.g. advanced testing, clinical examination by experienced physicians), will be addressed in the risk factor studies (Papers II-V). Hence, an explicit goal of the randomized controlled study (Paper I) was to prospectively examine whether predefined high-risk and low-risk criteria can be used as screening method. In concordance with the documentation mentioned earlier, this screening tool was simple; A history of previous injury or reduced function in the ankle, knee, hamstrings or groin was set as predefined high risk of injury.

The performance of a screening test

Sensitivity and specificity are statistical measures of the performance of a screening test. Sensitivity measures the proportion of actual positives which are correctly identified as such. Applied to screening in football medicine, sensitivity equals the odds of a positive test if the player actually did sustain a new injury. Specificity measures the proportion of negatives which are correctly identified (e.g. the odds of negative test of a predictor if the player did not sustain a new injury). These terms are closely related to type 1 and 2 errors; a type 1 error is when the null hypothesis is rejected, even though it is true (i.e. false positive), and type 2 error is when one fails to reject the null hypothesis even though it is wrong (i.e. false negative). A positive predictive value is a measure of the percentage of players with a positive test result given that they sustained a new injury, while a negative predictive value is the percentage of players with a negative test result given that they did not sustain a new injury during the following season.

Preventive measures

As early as 1983, Ekstrand and co-workers demonstrated a significant reduction in the overall number of football injuries through a 7-part prevention program (Ekstrand et al., 1983a). In this randomized controlled trial including 180 male amateur players in Sweden, a 75% reduction in injury incidence was found in the intervention group compared to the control group. The program included correction of training, equipment, prophylactic ankle taping, controlled rehabilitation, exclusion of players with knee instability, information and correction and supervision. Also, the rate of the most common types of football injuries, sprains and strains to ankles and knees, was reduced significantly. The following years, very little was done in the field of injury prevention in football. However, in recent years, especially after start of the present study, there has been a growth in preoccupation in sports injury prevention, illustrated by an abundance of scientific meetings and publications. However, relative to the magnitude of the problem, few injury prevention studies have been published in football until today; seven among female players (Hewett et al., 1999; Söderman et al., 2000; Heidt, Jr. et al., 2000; Mandelbaum et al., 2005; Soligard et al., 2008; Gilchrist et al., 2008; Steffen et al., 2008b), one among youth male players (Junge et al., 2002) and eleven (Including Paper I in this thesis) among senior male players (Ekstrand et al., 1983a; Tropp et al., 1985; Surve et al., 1994; Caraffa et al., 1996; Askling et al., 2003; Árnason et al., 2005; Hägglund et al., 2007; Árnason et al., 2008; Croisier et al., 2008; Hölmich et al., 2009). The preventive studies among male footballers are listed in table 6.

When focusing on adult male football players, the results are promising. Two years after the study by Ekstrand et al. (1983a), Tropp and co-workers (1985) had a more specific approach, looking at only ankle injuries. In a randomized controlled trial among 439 male amateur players in division VI in Sweden they found a significant reduction in ankle injuries among previously ankle injured players both after use of orthoses or neuromuscular training on an ankle disk. Later, Surve et al. (1994) confirmed these findings in a randomized controlled trial among 629 senior male players in divisions 1-4 in South Africa; players with previous ankle sprains had a significant risk reduction when using orthoses. Caraffa et al. (1996) evaluated neuromuscular training for prevention of knee injuries – the main difference from the ankle training program of Tropp et al (1985) being a slightly bent knee, compared to straight-leg training for the ankle, in that way focusing on knee control to achieve balance correction. They included 600 senior male semi-pro and amateur players in Italy and found a significant decrease in ACL injuries from the intervention. However, this was not a randomized controlled study.

As outlined earlier, joint injuries to the ankle and knee may have been the most frequent injuries previously, which may also explain the reason for the focus of the studies mentioned. More recently. Askling et al. (2003) carried out a randomized controlled trail among 30 male senior elite players in Sweden in order to reduce the risk of hamstring injury. Through eccentric overloading 1-2 times per week for 10 weeks they managed to increase strength and speed, and most importantly, reduce the number of hamstring injuries in the training group. It was later found in a much larger controlled trial among 17-30 elite teams in Iceland and Norway that eccentric strength training (Nordic hamstring lowers) combined with warm-up stretching appeared to reduce the risk of hamstring strains (Árnason et al., 2008). The same group had three years earlier published a study from the top two divisions in Iceland, where 271 players were educated in how injuries occurred to increase awareness and avoid injury situations (Árnason et al., 2005). Moreover, this video-based awareness program did not succeed in preventing injuries. Other preventive measures have been tested more recently; in a study among 582 amateur players at the

6th highest division level in Sweden, a coach-controlled rehabilitation program consisting of 10 steps, including return-to-play criteria, resulted in a 75% reduction in lower limb injuries. This underlines the importance of taking an injury and the rehabilitation seriously. More recently, 462 professional male players in the Belgian, Brazilian and French leagues were tested in the preseason and trained in order to compensate for strength imbalances of the hamstrings and quadriceps muscles. Interestingly, the rate of injured players was very low among players with no imbalances and significantly increased among players with untreated imbalances. The latter group had a more than a four-fold higher risk of sustaining a hamstring injury in comparison with the intervention group that had trained to normalize ratios. In addition to paper I in this thesis, the most recent prevention study among senior footballers was carried out among 977 amateur players in order to prevent groin injuries. Six exercises were implemented, including isometric adduction with the football between the feet, isometric adduction with a football between the knees, combined abdominal sit-ups and hip flexion, cross-country skiing on one leg, hip adduction against a partner's hip abduction and stretching of the iliopsoas muscle (Hölmich et al., 2009). There was a small, but non-significant reduction in the risk of groin injury found in this study. As can be seen from table 6, other preventive studies have been carried out in football, albeit among female or youth players.

Table 6. *Studies on prevention of injuries in football*

Reference (author, year)	Population	N	Injury definition	Study design	Preventive measure	Outcome measure	Study outcome
Studies on prevention of injuries in football among senior male players							
Ekstrand et al. 1983a	Senior male amateur players in Sweden	180	Time-loss (>1 week)	Randomized controlled trial	Prophylactic program in seven parts 1- Correction of training 2 - Equipment 3 - Prophylactic ankle taping 4 - Controlled rehabilitation 5 - Exclusion of players with knee instability 6 - Information 7 - Correction and supervision	Overall injury incidence	Reduction of 75% in injury incidence in the intervention group
Tropp et al. 1985	Senior male amateur players in Sweden, division VI	439	Time-loss (≥ 1 day)	Randomized controlled trial	Two interventions: -Orthosis -Neuromuscular training (ankle disc)	Ankle injury incidence	Significant reduction of ankle injuries in both ortosis- and ankle disc group
Surve et al. 1994	Senior male players in South-Africa Divisions 1-4	629	Time-loss (≥ 1 day)	Randomized controlled trial	Orthosis	Ankle injury incidence	Significant reduction of recurrent ankle sprains in orthosis-group
Caraffa et al. 1996	Senior male semi-pro/amateur players in Italy	600	ACL injury (arthroscopy)	Prospective controlled study	Neuromuscular (proprioceptive) training	ACL-injury	Significant decrease in ACL injuries in the intervention group (1.15 vs 0.15 injuries per team per year)
Askling et al. 2003	Senior elite players in Sweden	30	Time-loss (≥ 1 day)	Randomized controlled trial	Eccentric overloading in special device for 1-2 times/week for 10 weeks	Hamstring injury	Significantly fewer injuries in training group than controll group (3/15 vs 10/15). Also increased strength and speed.
Árnason et al. 2005	Senior elite players in Iceland Top two divisions	271	Time-loss (≥ 1 day)	Randomized controlled trial	Video-based awareness program	Overall injury incidence	No effect of the intervention on injury incidence. Also no difference in injury location or type.
Árnason et al. 2008	Senior elite players in Iceland and Norway	17-30 teams	Time-loss (≥ 1 day)	Prospective controlled study	Eccentric strength training (Nordic hamstring lowers) Flexibility training	Hamstring injury	Significantly lower hamstring strain incidence in teams training eccentric strength with Nordic hamstring lowers. No effect of flexibility training alone.
Hägglund et al. 2007	Senior amateur players in Sweden 6th highest level of play	582	Time-loss (≥ 1 day)	Randomized controlled trial	Coach-controlled rehabilitation program 10 steps, including return-to-play criteria	Re-injury	Significant reduction in injury risk in the intervention group. 66% risk reduction for all injuries 75% risk reduction for lower limb injuries

Croisier et al. 2008	Senior players in the Belgian, Brazilian and French professional leagues	462	1 – Physical examination 2 – Ultrasound/MRI 3 – Time-loss > 4 weeks	Cohort study	Preseason training to compensate for strength imbalance	Hamstring strain injury	Normalizing the isokinetic parameters reduced the risk for hamstring injury
Engebretsen et al. 2008 (Paper I in the present thesis)	Senior sub-elite players in Norway Division 1-3	525	Time-loss (≥ 1 day) Also non-time-loss injuries were included for hamstring and groin	Randomized controlled trial	Neuromuscular training Nordic hamstring lowers Groin strength training	Sum of Ankle, Knee, Hamstring and Groin injuries	No significant effect of intervention exercises Poor compliance.
Hölmich et al. 2009	Senior amateur players in competitive level	977	Medical attention	Cluster randomized controlled trial	Six exercises 1- Isometric adduction with football between feet 2 - Isometric adduction with football between knees 3 – Combined abdominal sit-up and hip flexion 4 – Cross-country skiing on one leg 5 – Hip adduction against a partner's hip abduction 6 – Stretching of the iliopsoas muscle	Groin injury	No significant effect of the intervention exercises
Studies on prevention of injuries in football among male youth players or among players of both genders							
Hewett et al. 1999	Female high school athletes in football, volleyball or basketball in the U.S.A. Male controls	1263	Serious knee injury defined as time-loss≥5 days. ACL injury (confirmed arthroscopically)	Prospective controlled study	6 week preseason neuromuscular training program (Incorporates flexibility, plyometrics and weight training)	Knee injury	Significant decrease in knee injury incidence
Söderman et al. 2000	Senior female players in Sweden 2nd and 3rd division	221	Time-loss (≥ 1 day)	Randomized controlled trial	Neuromuscular training Balance board on flexed knee	Knee injury ACL injury Lower extremity injury	No significant differences between the groups with respect to either number, incidence or type of traumatic injuries of the lower extremities
Heidt et al. 2000	Youth (14-18 years) female players in the	258	Time-loss (≥ 1 day)	Prospective controlled	Pre-season conditioning program	Overall injury incidence	Significantly lower injury incidence in the trained group

	US.			study	(The Frappier Acceleration training program, 7 weeks)		(Lower percentage ACL injuries, but not statistically significant)
Junge et al. 2002	Youth (14-19 years) male players in Switzerland (3 high skill, 4 low skill teams)	263	Time-loss (≥ 1 day) or physical complaint that lasted for more than 2 weeks	Prospective controlled study	General intervention -improvement of warm-up -regular cooldown -Taping of unstable ankles -Adequate rehabilitation -Promotion of fair play Specially designed F-MARC Bricks -10 sets of exercises designed to improve the stability of joints, flexibility, strength, coordination, reaction time and endurance	Overall injury incidence	Significantly fewer injuries in the intervention group The greatest effects were observed in low-skill teams
Mandelbaum et al. 2005	Youth (14-18 years) female players in the US	2946 + 2757	Only non-contact ACL-injuries were registered (Confirmed by MRI or arthroscopy)	Nonrandomized controlled trial	Sports-specific intervention over a 2-year period -Education -Stretching -Strengthening -Plyometrics -Sports-specific agility drills	Incidence of non-contact ACL-injuries	There was an 88% decrease in non-contact ACL injury the first year, and 74% decrease the 2nd year
Steffen et al. 2008	Youth female (Under-17 league) players in Norway	2092	Time-loss (≥ 1 day)	Cluster randomized controlled trial	F-MARC 11 -Core stability -Balance -Plyometrics -Strength	Overall injury incidence	No effect of the intervention program Poor compliance
Gilchrist et al. 2008	Female players in Division I in the US	1435	Time-loss (≥ 1 day)	Cluster randomized controlled trial	PEP program consisting of stretching, strengthening, plyometrics, agilities, and avoidance of high-risk positions depicted on a video	Non contact anterior cruciate ligament injury	A decrease in total (contact + noncontact) ACL injury rates
Soligard et al. 2008	Youth (13-17 years) female players in Norway	1892	Time-loss (≥ 1 day)	Cluster randomized controlled trial	Comprehensive warm-up "11+" -Strength -Awareness -Neuromuscular control	Lower extremity injury	Significant reduction in overall injury incidence. Also severe and overuse injuries were reduced. No effect on knee, match, training or acute injuries

Exercise programs to prevent injuries

As described above, injuries to the ankle, knee, hamstring and groin constitute the majority of injuries in football. We therefore chose these four injury locations as our main focus areas. According to the above mentioned studies on prevention of injuries in football, it seemed as though neuromuscular training programs with straight and bent knee were useful in the prevention of ankle and knee sprain injuries respectively. For strain injuries of the hamstrings and groin, there existed indications of preventive effects of strength training. However, as outlined, relative to the magnitude of the problem, little was known about effective preventive exercises. Therefore, there was a need to test whether neuromuscular training and strength training could reduce the number of injuries in football. This was therefore tested in the present thesis in a randomized controlled trial (Paper I).

Ankle injuries. Regarding ankle injuries, the two important studies among male, senior football players (Tropp et al., 1985; Surve et al., 1994) found a significant reduction in incidence of ankle injuries after use of mechanical support in the form of orthosis or taping. Also one of the seven preventive actions taken by Ekstrand et al (1983a) in their study was prophylactic taping of previously injured ankles. Despite significant injury reduction, it is not possible to tell if that measure alone, or any of the other measures caused that effect, although it is supported by the above mentioned studies. A systematic review (Thacker et al., 1999) and two Cochrane reviews (Quinn et al., 2000; Handoll et al., 2001) concluded that there is good evidence for the beneficial effect of ankle supports in the form of orthoses. Although this reduction was greater for players with a previous history of ankle sprain, the effect was still observed for those without prior sprain. However, it is also stated that any potential prophylactic effect should be balanced against the baseline risk of the activity, the supply and cost of the particular device, and for some, the possible or perceived loss of performance. The latest Cochrane review (Handoll et al., 2001) (2005 update) also states that there was limited evidence for reduction in ankle sprain for those with previous ankle sprains who did ankle disk training exercises. Even though no studies on performance and perceived performance exist, there seems to be a negative attitude to using orthoses among football players in our opinion.

Neuromuscular training, especially among previously injured players/athletes, has shown promising effects among male, senior footballers (Tropp et al., 1985) and among athletes in other sports (Wester et al., 1996; Bahr et al., 1997; Verhagen et al., 2000) and in rehabilitation programs (Holme et al., 1999). In the study by Tropp et al. (1985), the ankle disc training was performed with one leg extended straight and the other raised and flexed at the knee. For the first 10 weeks the training time was 10min five times weekly with one or both legs, depending on the previous problems, and then 5 min three times weekly. As stated above, this training resulted in a significant injury reduction.

We wanted to test such exercises further and therefore chose to use neuromuscular training exercises as the measure to prevent ankle injuries in the present study (Paper I). Similarly to the study by Tropp et al. (1985) all exercises were prescribed to be performed with a straight leg (no knee flexion) (see Figure 2, Paper I) and with a gradual progression in difficulty. The players were instructed to switch between the balance board and pad, and, as they became more proficient, to include ball-based exercises while keeping their balance. A complete description of the ankle exercises may be seen in Table 1, Paper I.

Knee injuries. As mentioned above, neuromuscular training has proven effective in reduction of ankle injuries among male, senior footballers (Caraffa et al., 1996) and in other study populations (Heidt, Jr. et al., 2000; Junge et al., 2002; Olsen et al., 2005). In regards of football specific interventions, the study by Caraffa et al. (1996) included 600 footballers in 40 semiprofessional or amateur teams. Three hundred of these were instructed to train 20min per day with five different phases of increasing difficulty. The training was performed on four different types of wobble-boards wich ensured increasing difficulty. Despite a highly significant injury reduction in this study, a systematic review of prevention of knee injuries in sports (Thacker et al., 2003) concludes that structured training programs that emphasize neuromuskular and proprioceptive training offered encouraging evidence for the prevention of knee injuries, but that rigorously implemented research programs are needed. We therefore tested a preventive program consisting of neuromuscular training exercises based on the study by Caraffa et al. (1996) in the intervention study (Paper I). As with the ankle program, the players were instructed to switch between the balance board and pad, and include ball-based exercises as they progressed.All exercises were prescribed to be performed with the knee-over-toe position and a flexed knee (Figure 3, Paper I) with gradual progression in difficulty. A complete description of the knee exercises may be seen in Table 2, Paper I.

Other training regimens have been suggested in different sports or player populations, such as knee bracing (Albright et al., 1994), education and enhanced awareness of dangerous positions and mechanisms of non-contact ACL injury (Johnson RJ, 2001) or strength training. However, these studies provide limited evidence or relevance for our player population. A systematic review of prevention of knee injuries in sports (Thacker et al., 2003) concluded that there was no consistent evidence of benefit from bracing. Because of inadequate reporting of methodology, two studies comparing alternative cleat designs and a controlled study testing the effects of adjustments in the ski boot/binding system were difficult to interpret.

Hamstring injuries. The pilot study by Askling et al (2003) observed a reduction in hamstring strains through eccentric strength-training programs. The Nordic hamstring exercise is performed standing on the knees on a soft foundation, slowly lowering the body toward the ground using the hamstrings while the feet are held by a partner (Figure 5, Paper I). Progression is achieved by increasing the initial speed, and eventually having a partner push forward. Until study start, other methods for injury reduction such as thermal pants (Upton et al., 1996) and stretching (Herbert & Gabriel, 2002) had been suggested, but with no definite conclusions in regards of injury prevention. Strength training therefore seemed to be the most promising preventive measure, and a randomized controlled trial was necessary to test this properly. The Nordic Hamstring Lowers program was therefore tested in the study described in Paper I. A complete description of the training program may be seen in Table 4, Paper I.

Groin injuries. Similarly to hamstring injuries, stretching had for a long time been believed to be preventive in regards of groin strain injuries. However, a recent review concluded that stretching does not confer protection from muscle soreness or useful reduction of injury risk, in contrast to the previously reigning understanding on the topic (Herbert & Gabriel, 2002).

A study by Hölmich et al (1999) showed that an active training programme aimed at improving strength and coordination of the muscles acting on the pelvis was very effective in treatment of athletes with long-standing adductor-related groin pain. The authors proposed that a short programme based upon the principles of such an active training programme should be assessed in future, randomized clinical trials in order to examine the potential preventive value. Until start of the present study, the preventive effect of such a program had however not been tested in a randomized trial. In the present prospecitve controlled trial (Paper I), such strength exercises were put together in a shortened program to address this need. The players were therefore instructed to perform the exercise 3 times a week for approximately 15 min. A ball was needed for some of the exercises (Figure 4, Paper I), and the exercises could be performed without warming up. A complete description of the ankle exercises may be seen in Table 3, Paper I.

Aims of the thesis

1. To test whether we could identify players with an increased risk of injury using a questionnaire focusing on history of previous injury and joint/muscle function
2. To examine if exercise programs targeting players with an increased risk of injury could prevent the four most common injury types in football; ankle and knee sprains and hamstring and groin strains
3. To investigate possible risk factors for acute ankle injuries
4. To investigate possible risk factors for acute knee injuries
5. To investigate possible risk factors for hamstring injuries
6. To investigate possible risk factors for groin injuries

Methods

The same players and testing were used for all articles (Paper I-V). A randomized controlled trial was carried out to prevent injuries (Paper I). Papers II-V are cohort studies on risk factors and were carried out focusing on potential risk factors for ankle (Paper II), knee (Paper III), hamstring (Paper IV) and groin injuries (Paper V).

Participants

A total of 35 teams (n=769 players) from the Norwegian 1st, 2nd or 3rd division of football for men, geographically located in the proximity of Oslo, were invited to participate in the study. In Norway, there are several different 3rd division conferences, and the 3rd division teams included either won their conference or finished as first runners up the previous season, resulting in a relatively homogenous group of teams, even if the 35 teams competed in three different divisions. Three of the teams (n=60 players) declined the invitation to participate, 177 players did not report for testing, three players did not speak Norwegian and could therefore not complete the questionnaire and four players were excluded for other reasons (See flow chart, figure 1, paper I). Hence, 244 of the players invited could not be included. In addition, one team (n=17 players) was later excluded because the physiotherapist did not record injuries, resulting in a final sample of 508 players representing 31 teams from three divisions (1st division, n=7, 122 players; 2nd division, n=16, 260 players; and 3rd division, n=8; 126 players).

Preseason testing

During the preseason (January through March 2004) the teams were tested at the Norwegian School of Sports Sciences through a questionnaire and specific tests for potential risk factors. The questionnaire was in five parts. The first section consisted of general information (date of birth, team, field position, and player experience). The second through fifth sections included information about the ankle (Paper I and II), knee (Paper I and III), hamstring (Paper I and IV), and groin (Paper I and V), respectively. Each of these sections covered the history of previous injuries (severity, nature, and number of months since the most recent injury, use of protective equipment such as tape or brace, and if the injury had caused the player to miss matches), and a function score for each region. The questionnaires used to assess function were the Foot and Ankle Outcome Score (FAOS) (Paper I and II) and Knee Osteoarthritis Outcome Score (KOOS) (Paper I and III), which were translated to Norwegian (Roos et al., 1998; Roos et al., 2001). These forms consist of five major parts (symptoms, pain, activities of daily living, function in sports and recreation, quality of life) and are scored by calculating the mean value of the five parts in percent of the total possible score, where 100% is the maximal and 0% the lowest score. For the hamstring and groin, we developed similar function scores, the Hamstring Outcome Score (HaOS) (Paper I and IV) and Groin Outcome Score (GrOS) (Paper I and V), based on the same principles as FAOS and KOOS, only specific to these regions and their typical symptoms (see Appendix to Paper I). For the HaOS and GrOS, we replaced the category "function in daily living" with a category on muscle soreness.

Second, every player capable (not injured at the time) completed specific tests for ankle, knee, hamstring and groin and were also examined clinically for these four regions. The specific tests consisted of single leg balance tests for both legs, both on a balance mat and on the floor (Paper II), three counter movement jumps, two 40 m sprint tests (Paper III, IV, V), a Nordic hamstring strength test, hamstring length measurement (Paper IV) and an isometric adductor strength test (Paper V). Detailed descriptions of these tests are provided in Papers II-V.

The clinical testing of the players was performed by a group of ten sports physical therapists and sports physicians who were blinded for any injury history (scars were not concealed). Both legs were examined thoroughly, including a structural examination of the ankle, knee, hamstring and groin.

Study design

For the randomized controlled trial (Paper I), the 508 players were divided into two groups, a high-risk (HR) and a low-risk (LR) group based on information from the questionnaire. The criteria for classifying a player as having an assumed increased risk of injury were a history of an acute injury to the ankle, knee, hamstring or groin during the previous 12 months or a reduced function with an average score of less than 80% for any of the body parts mentioned. A player fulfilling any of the inclusion criteria for any of the four body parts was assigned to the HR group. The players in the HR group were randomized individually, but stratified within each team, into 2 groups, the HR intervention group and the HR control group (see Figure 1, Paper I). In this way, each team would normally have players from all three groups (HR intervention, HR control, and LR control). The players in the HR intervention group were only included on the basis of the inclusion criteria that they fulfilled, meaning that they only received a training program for the body part(s) assumed to have an increased risk of injury. In a situation in which a player ended up with four programs, the team physical therapist was asked to merge the programs into one continuous program. However, even if a player fulfilled the inclusion criteria for one body part on only one side, he was asked to perform the prevention exercises for both legs. The players were asked to complete the ankle, knee, and groin training programs three times a week for 10 weeks during the preseason, in separate training sessions done outside the regular team training. For the hamstring program, a 10-week progression was prescribed (Mjølsnes et al., 2004). The intervention players were also asked to perform the exercises once per week for the rest of the season as maintenance. The programs were meant to progress in difficulty, to challenge the players as their performance improved. The players were also asked to report all exercises they performed on a form, checking a box if they had carried out the preventive training that day. The form covered all 10 weeks for compliance assessment. A more detailed description of the training programs can be found in paper I.

The prospective cohort studies on risk factors for ankle (Paper II), knee (Paper III), hamstring (Paper IV) and groin (Paper V) injuries are based on the same data as the randomized trial (Paper I). Because no differences were seen in injury rates between the intervention and control groups (see Results section later), the entire cohort could be used to examine the effect of a number of risk factors assessed at baseline.

Injury definition

An injury was defined as any physical complaint sustained by a player that resulted from a football match or football training, resulting in a player being unable to take a full part in future football training or match play ("time-loss" injury). Acute injuries were defined as injuries with a sudden onset associated with a known trauma, whereas overuse injuries were those with a gradual onset without any known trauma. Injuries were classified into three severity categories according to the time it took until the player was fully fit to take part in all types of organized football play: minor (1-7 days), moderate (8-28 days), and major (>28 days).

All injuries were categorized by the authors based on the injury reports from each physiotherapist. For the purpose of the different papers, an injury was classified as ankle sprain if it was recorded as an acute injury of the ankle ligaments (Paper II), knee injury if it was recorded as an acute injury of the knee ligaments, menisci, bone or joint cartilage, or if hemarthros had occurred as a result of knee sprain (Paper III), hamstring strain if it was recorded as either an acute or an overuse muscle injury of the posterior thigh (Paper IV) and groin strain if it was recorded as either an acute or an overuse injury of medial thigh (Paper V). Overuse injuries where there was no time loss were included to incorporate small repeated hamstring or groin strain injuries, as some players still elect to play despite discomfort. For such an injury to be recorded, the player would have to get in contact with the physiotherapist, i.e. fulfilling the criteria for a "medical attention" injury; an injury that results in a player receiving medical attention, not necessarily forcing the player to miss taking full part in future football training or match play. The head coach for every team registered each player's participation in training and the number of minutes played in matches. For the randomized controlled trial (Paper I), the main outcome measure was the sum of the risk for an ankle sprain, knee sprain, groin strain or hamstring strain.

We later found the injury definitions used to be in concordance with the consensus statement by the Injury Consensus Group convened by FIFA in 2006 (Fuller et al., 2006).

Match exposure was defined as play between teams from different clubs, while training exposure was defined as team-based and individual physical activities under the control or guidance of the team coaching or fitness staff aimed at maintaining or improving football skills or physical condition.

Injury registration

The team physical therapist was responsible for reporting injuries on their team throughout the preseason and the season. Most of the teams from the 1st and 2nd divisions already had a physical therapist working with the team. When there was no physical therapist attached to the team, we provided them with one. Each physical therapist was rewarded with a stipend (10 000 NOK, or approximately 1700 USD). In addition to reporting injuries throughout the preseason and season, the physical therapist was responsible for instructing all the players who were randomized into the HR intervention group in their training programs. Each player was given a folder describing the exercises he was asked to do, as well as any necessary equipment such as balance mats and balance boards.

Statistical methods

Exposure was calculated in hours as the sum of all individual exposures recorded during training and match play during the season.

For the randomized controlled trial (Paper I), the injury rate was compared between the HR control group and the HR intervention group, and the HR control group and the LR control group, respectively, using a z test, reporting 95% confidence intervals (CIs) based on the Poisson model. Chi-square tests were used to compare the proportion of injured players between the HR intervention group and the HR control group, and between the HR control group and the LR control group, respectively. Otherwise, results are presented as the means with standard deviations.

The sample size calculation is based on injury frequences from the elite division in Norway and the two top divisions in Iceland (Árnason et al., 1996; Andersen et al., 2004b; Andersen et al., 2004c). Based on those studies, we expected at least 50% of the players in our study to obtain an injury in either the ankle, knee, groin or hamstring. We hoped to detect at least a 30% reduction of injury in the intervention group compared to the control group. With a β-value of 0.20 and an α-value of 0.05 and with excess margins to account for possible drop-out, there was a need of approximately 30 teams with 20 players each. We therefore invited 35 teams, and 32 teams agreed to be included in the study.

For the continuous dependent variable risk factor analyses (Papers II-V), where each leg was the unit of analysis, generalized estimating equations (STATA, version 8; STATA, Texas, U.S.A.) were used, accounting for total individual exposure during the football season, any within-team correlations and the fact that the left and right foot belonged to the same player. Ankle, knee, hamstring or groin injury during the season was set as the dependent variable respectively, while total hours of football play during match and training was set as the total exposure. To account for the dependency within persons due to analyses by each leg as unit, the correlation pattern was chosen as unstructured, i.e. without any presumption about its structure. Logistic regression analyses were used to examine the relationships between per subject calculated dichotomous injury variables and their risk factors. All risk factor variables were examined in univariate analyses, and those with a P value <0.10 were investigated further in a multivariate model. P values of <0.05 were considered as statistically significant.

Reliability testing for the risk factor studies

Inter-test reliability was examined for the single leg balance test (Paper II), hamstring muscle length measurement (Paper IV), the Nordic hamstring strength test (Paper IV), adductor strength test (Paper V) and the clinical examination of ankle (Paper II) and knee (Paper III) by having the same player repeat the same test with different personnel after he had completed the first test. Each examiner was blinded to the other's results. The same scoring system/clinical forms were used at both stations. Inter-test reliability for the categorical variables was computed using kappa statistics, while the coefficient of variation for the continuous variables was calculated as the standard deviation of the difference between the first and second test as a percentage of the average test results for both tests.

Ethics

The study was approved by the Regional Committee for Medical Research Ethics, Helse Øst, and written consent was obtained.

Results and discussion

Overall results

Player exposure (Paper I-V)

The total exposure to match play (19008 hours) and training (89103 hours) was 108 111 player hours. In regards of the intervention study, there was no difference in mean player exposure between the HR intervention group (217 ± 94 hours), the HR control group (210 ± 103 hours) and the LR control group (211 ± 88 hours).

Incidence of injuries (Paper I-V)

An overview of the injuries reported in Papers I-V can be found in table 7.

Incidence of ankle injuries (Paper II)

A total of 34 players sustained one ankle injury, while 6 and 2 players sustained two and three injuries, respectively. One player sustained four ankle injuries throughout the season. Of the 56 injuries, 34 occurred on the right side, while 22 were on the left.

Incidence of knee injuries (Paper III)

A total of 46 players sustained one knee injury, six sustained two injuries, and one player sustained three injuries. Of the 61 injuries, 30 occurred on the right and 31 were on the left side.

Incidence of hamstring injuries (Paper IV)

A total of 48 players sustained one hamstring injury, 11 sustained two injuries, and two players sustained three injuries. Of the 76 injuries, 40 occurred on the right side and 36 were on the left side. In five overuse injuries, there was no time loss

Incidence of groin injuries (Paper V)

A total of 44 players sustained one groin injury, five sustained two injuries, one sustained three injuries and one player sustained four injuries. Of the 61 injuries, 31 occurred on the right side and 30 on the left. In two overuse injuries there was no time loss.

Table 7. *Injury incidence (With 95% Confidence Intervals)*

	Injury incidence (Injuries per 1000playing hours)			Number of injuries		Number of injured		Injury severity			
	Overall	Training	Match	Total	Acute	Players	Legs	Minor (1-7d)	Moderate (8-28d)	Severe (>28d)	Not specified
All injuries	4.7 (4.3-5.1)	2.7 (2.4-3.1)	12.1 (10.5-13.7)	505	353	283 (56%)	-	217	174	82	32
Ankle injuries	0.5 (0.4-0.7)	0.3 (0.2-0.4)	1.5 (0.9-2.0)	-	56	43 (8.5%)	46	26	22	5	3
Knee injuries	0.6 (0.4-0.7)	0.3 (0.2-0.4)	1.8 (1.2-2.5)	-	61	53 (10.4%)	57	10	26	23	2
Hamstring injuries	0.7 (0.5-0.9)	0.3 (0.2-0.4)	1.8 (1.2-2.5)	76	51	61 (12.0%)	65	25	31	10	5
Groin injuries	0.6 (0.4-0.7)	0.3 (1.2-2.5)	1.8 (1.2-2.5)	61	22	51 (10.0%)	55	29	17	12	1

Injury incidence (Papers I-V) compared with other studies

As can be seen from table 1, there was a lower injury incidence reported in the present studies (12.8 injuries /1000 match hours) compared to previous studies among senior male footballers (25 - 35 injuries /1000 match hours) (Ekstrand & Gillquist, 1983a; Árnason et al., 1996; Hawkins & Fuller, 1999; Andersen et al., 2004b; Waldén et al., 2005a; Waldén et al., 2005b). This could partly be explained by the lower level of play, but it could also be that our recording system did not capture all injuries. When using a time-loss definition of injury the definition depends on the frequency of training sessions and matches, and can therefore cause bias when comparing different levels of play. The physical therapists were rewarded with a stipend, but the resources were not sufficient to allow for daily follow-up of the teams by the physical therapist. Thus, there is a potential bias in injury reporting depending on the availability of the physical therapist, at least for minor injuries. However, it may be expected to have influenced all players, not any players with specific risk factors. Therefore, the greatest consequence of missing cases would be loss of statistical power. The same would probably be the case for the intervention outcome as well.

A recent publication documented that prospective injury surveillance by team medical staff in Norwegian male professional football underestimates the incidence of time-loss injuries by at least one-fifth (Bjørneboe J et al., 2009). It seems reasonable to assume that this underestimation may be even higher at lower levels, where follow-up is less consistent as in professional football.

Mahler and Donaldson (2010) even announced a theory on a "threshold" incidence of injuries, below which it might be difficult to go. Because the injury incidence in our study was so low, it may be difficult to go any lower. However, a recent study from lower level senior male football (sixth highest division) (Hägglund et al., 2007) also resulted in lower injury rates than from the elite level, in correspondance with the present findings (Paper I). A study from the early 1980s also shows that the injury incidence in amateur football in Sweden was not that different from our results (Ekstrand et al., 1983b).

Prevention of injuries (Paper I)

In the LR control group there were 82 injuries, while there were 216 injuries in the HR control group and 207 injuries in the HR intervention group. There was no difference in the incidence of injuries between the HR intervention group and the HR control group (RR: 0.94, 95% CI: 0.77 to 1.13). Also, no difference in injury severity was seen between any of the three groups (Figure 2).

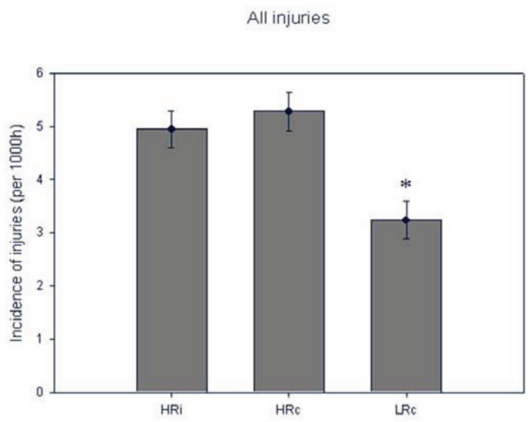

Figure 2. *Intention-to-treat analysis – overall injury rates.*

Intervention outcome – intention-to-treat analysis (Paper I)

For the main outcome measure, the sum of injuries to the ankle, knee, hamstrings and groin, the total incidence was 2.3 injuries per 1000 playing hours (95% CI: 2.1 to 2.6). There was a significantly lower injury risk in the LR control group compared to the two other groups (RR: 0.49, 95% CI: 0.33 to 0.71 vs the HR control group; RR: 0.53, 95% CI: 0.36 to 0.77 vs the HR intervention group). However, no difference was seen between the HR intervention group and the HR control group (RR: 0.93, 95% CI: 0.71 to 1.21) (Figure 3).

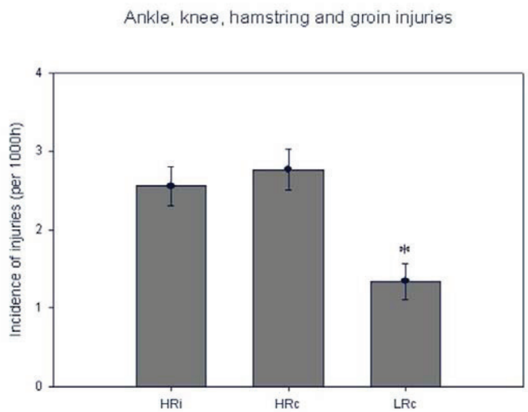

Figure 3. *Intention-to-treat analysis for the main outcome measure, the sum of injuries to the ankle, knee, hamstrings and groin.*

When the players in the HR intervention and HR control groups with increased risk of injury were compared, we found no significant differences in the risk of injury to the body part in question between the two groups for any category (ankle: RR 0.64, 95% CI: 0.32 to 1.29; knee: RR 0.96, 95% CI: 0.35 to 2.64; hamstrings: RR 1.55, 95% CI: 0.83 to 2.90; groin: RR 1.18, 95% CI: 0.55 to 2.54) (Table 7, Paper I).

Compliance with the training program and per-protocol analysis (Paper I)

Compliance with the training programs in the HR intervention group was poor, with only 27.5% (28 players) in the ankle group and 29.2% (19 players) in the knee group having completed 30 or more training sessions. For the hamstring and groin exercises, compliance was even less, with only 21.1% (12 players) and 19.4% (16 players) completing 20 or more training sessions, respectively. Hence, the compliant (more than 30 exercises for ankle and knee, and more than 20 training sessions for hamstring and groin) groups are small. As many as 15.7% (16 players) reported not having done any ankle exercises, 11.8% (12 players) 1-9 exercise sessions, 24.5% (25 players) 10-19 sessions, while 20.6% (21 players) reported having carried out 20 or more sessions, but less than the target number of 30. The corresponding figures for knee exercises were 23.1% (0 exercise sessions reported), 9.2% (1-9 sessions), 13.8% (10-19 sessions) and 24.6% (20-29). For hamstring exercises the figures were 63.2% (0 exercise sessions reported), 7.9% (1-9 sessions) and 7.9% (10-19 sessions), and finally for groin exercises 67.7% (0 exercise sessions reported), 4.8% (1-9 sessions) and 8.1% (10-19 sessions).

In a per-protocol analysis on ankle injuries, the incidence of ankle injuries in the compliant group, which sustained 3 injuries (2 of 28 injured players), was 0.5 (95% CI: -0.1 to 1.0) injuries per 1000 hours, compared to 0.9 (95% CI: 0.5 to 1.3) injuries per 1000 hours among players with an increased risk of ankle injuries in the HR control group (RR=0.51, 95% CI: 0.2 to 1.7). Similarly, we could not detect any difference in the risk of knee injury between players in the HR intervention group who were compliant with the knee program (0.2 (95% CI: -0.2 to 0.7) injuries per 1000 hours) and the high-risk players in the HR control group (0.5 (95% CI: 0.2 to 0.9) injuries per 1000 hours, RR 0.46, 95% CI: 0.1 to 3.7). In the same way, no difference was observed in the incidence of hamstring (RR 0.94, 95% CI: 0.3 to 3.2) and groin injuries (RR 1.6, 95% CI: 0.5 to 5.6) between players in the HR intervention group who were compliant with the respective training programs and the HR control group.

Injury registration

One limitation of the intervention study is the difference in physical therapist contact between the HR intervention players and the other groups. To instruct in the intervention exercises, the physical therapist became well acquainted with each of the intervention players, and not always to the same extent with the other players in the team. Thus, there was a potential for a bias in injury reporting, because the same physical therapist also was responsible for reporting injuries. Because the HR intervention players constitute approximately half of the high risk players this also causes a potential bias for the risk factor studies. In this way, an increased amount of players with previous injuries could have had resulted in a slightly higher injury reporting rate.

The preventive measures (Paper I) compared with other studies

The most likely explanation for the abscence of any detectable effect of the targeted intervention on injury risk, was the low compliance with the exercise programs. With such low compliance in the intervention group (ranging between 20% and 30% for the different exercise programs), no effect could be expected on decreasing the injury rate.

In contrast to most previous intervention studies, players were randomized individually to the intervention or control group in the present study. We relied on the team physical therapists to instruct the players in the intervention program. However, to avoid contamination the players were asked to do the exercises outside the regular team training sessions; before or after training or at home. The low overall compliance in the intervention group indicates that significant contamination between groups is unlikely to have occurred. As seen in previous studies, the main challenge is getting players in the intervention group to follow preventive training programs, not keeping other players from such training (Myklebust et al., 2003).

However, a potentially bigger risk of contamination is the fact that 19 of the 31 teams did team-based preventive exercises similar to ours regularly throughout the pre-season, and 16 of these reported good training regimens. Also, we could not keep teams from carrying out their normal preventive exercises. Although these team-based exercises were done by players in both groups, the fact that players from the control group trained with exercises similar to our intervention exercises, did reduce the potential of showing a positive preventive effect of our intervention, and represents a limitation in this study. Moreover, exercises carried out by each player on his own are probably not as effective as when they are carried out under qualified supervision (Söderman et al., 2000), not just because of a lower compliance, but also because the quality of the exercises performed cannot be assured in the same way. Potentially negative factors such as initial muscle soreness or eventual boredom could possibly be overcome more effectively in a group training session with a qualified instructor.

Because the compliance was low, the statistical power was also too low to assess the effect of the training programs in the subgroups which did follow the training protocol (i.e. through the per-protocol analyses). The four programs used were selected either because there was evidence from previous prevention studies to indicate that they are effective, or because they have been shown to be effective as rehabilitation exercises after injury.

Prevention of ankle injuries

To prevent ankle and knee injuries, various forms of balance training and pre-season conditioning exercises had been shown to be effective in other study populations (Tropp et al., 1985; Caraffa et al., 1996; Heidt, Jr. et al., 2000; Verhagen et al., 2000; Junge et al., 2002). Since the study was carried out, also later studies and systematic reviews have reported that neuromuscular training can prevent ankle injuries (Verhagen et al., 2004; Stasinopoulos, 2004; Mohammadi, 2007; McKeon & Mattacola, 2008; Lee & Lin, 2008; Hupperets et al., 2008; Melnyk et al., 2009; Hupperets et al., 2009; Hubscher et al., 2010). Of all intervention strategies, the most consistent evidence supports the use of external support, either through use of orthoses or taping, especially among previously injured players (Thacker et al., 1999; Handoll et al., 2001; McKeon & Mattacola, 2008). However, the use of orthoses may influence performance (Bot & van Mechelen, 1999) in sports in general, and obviously football in particular. As we also demonstrated in the present study (Paper I), achieving a good compliance with our preventive measures is difficult, and we did not believe implementing the use of orthoses would be well received by the players. Hence, taping was thought to be the only option for external support that could be implemented. However, including this measure on such a big sample of players would be challenging to achieve in a standardized method. Also, as a main goal of the present study was to develop means available to all players, not just the elite players with good medical staff, we believed neuromuscular training would be of the greatest use.

Prevention of knee injuries

Since the study was carried out, also later studies and systematic reviews have found that neuromuscular training can prevent knee injuries (Thacker et al., 2003; Mandelbaum et al., 2005; Olsen et al., 2005). Only one study has not found such training useful (Söderman et al., 2000). Regarding bracing as preventive means for knee injuries, a systematic review in collegiate American football players concluded that the results on the area of research are inconsistent. Also, bracing seems to influence performance (Greene et al., 2000).

Prevention of hamstring injuries

Until the start of our study, recent publications had indicated that strain injuries to the hamstrings could be effectively prevented through eccentric strength training, such as the training program used in the present study (Askling et al., 2003; Mjølsnes et al., 2004; Árnason et al., 2008). Later, a prospective cohort study achieved significant reduction in injury risk through normalization of strength imbalances detected in the preseason (Croisier et al., 2008). A review from 2005 concluded that there was a need for further research on hamstring injury prevention in sports (Petersen & Hölmich, 2005). A systematic Cochrane review has later looked at hamstring preventive exercises (including Paper I from the present thesis), and concluded that there is insufficient evidence from randomised controlled trials to draw conclusions on the effectiveness of interventions used to prevent hamstring injuries (Goldman & Jones, 2010). Regarding other preventive measures, a systematic review from 2004 (Thacker et al., 2004) concurred with the review from two years earlier (Herbert & Gabriel, 2002) and concluded that stretching was not significantly associated with a reduction in total injuries. This seems to be in contrast to Witvruov et al. who concluded that soccer players with an increased tightness of the hamstring muscles have a higher risk for a subsequent musculoskeletal lesion (Witvrouw et al., 2003).

Prevention of groin injuries

Equivalent to the exercises chosen for hamstring injuries, strengthening exercises were chosen for prevention of groin injuries as well. As stretching did not seem useful (Herbert & Gabriel, 2002), strength training was the most promising preventive measure. The program of strength training and core stability had been shown to be highly effective in the treatment of long-standing groin pain in a population mainly consisting of football players (Hölmich et al., 1999). This program formed the basis for the present program, but because we thought it would be unrealistic to implement the entire groin program, we prescribed an abbreviated 10-15 minute session to increase compliance. Unfortunately, the results show that compliance was still poor, and therefore the true effect of the preventive program carried out cannot be assessed. The same group that suggested using strength training not only for treatment for chronic groin pain, but also in means of prevention, recently tested such a program in a large cluster-randomized controlled study. However, there was no significant reduction in groin injury incidence as a result of such training (Hölmich et al., 2009).

General considerations regarding prevention of injuries

In other words, each of the program components were based on studies indicating their effect in prevention or rehabilitation of the four main injury types. However, previous injury as a risk factor is not fully understood; it may be that ankles, knees, hamstrings and groins are not fully restored structurally or functionally. While the injury prevention literature supports several different exercises, there is limited evidence that reinjuries would be prevented through the same exercises. We do not know which exercises should be chosen to prevent reinjuries, and which have potential for primary prevention of the same injury types.

It is possible that the compliant players may have benefited from the programs if they had carried out more sessions. We know that a certain minimum of exercise must be performed before an effect may be expected (Myklebust et al., 2003). For the purposes of data analysis, we suggested that at least 30 exercises needed to be carried out. However, this number is arbitrary, as there is no evidence on the dose-effect relationship for any exercise program to prevent injuries.

Risk factors for the most common injuries in football (Papers II-V)

Because these studies (Papers II-V) were based on the randomized controlled trial (Paper I), separate analyses controlling for group assignment (intervention or control group) were performed; however, with no change in the results for neither ankle (Paper II), knee (Paper III), hamstring (Paper IV) nor groin (Paper V) analyses. Also, a Poisson model approximating multinomial logistic regression analyses was used, in order to compare players who sustained no injuries versus those who sustained one injury versus those who sustained more than one injury. Again, the results did not differ from the original analyses. The risk factor analyses presented below therefore includes all players, regardless of team and group assignment.

Risk factors for ankle injuries (Paper II)

Univariate analyses revealed the number of previous acute ankle injuries and the FAOS sub score "Pain" as potential leg-dependent risk factors for acute ankle injuries. None of the balance tests on the floor or a balance mat, or clinical tests were candidates predictors for increased risk. Additionally, none of the player-dependent factors (age, height, body mass index, position on the field, having played at the junior national team or at the senior national team level, level of play this season or level of play the previous season) were significantly associated with the risk of ankle injury.

The two risk factors with p-value of <0.10 were then considered as candidates to predict which players were more prone to sustain an acute ankle injury. Because these factors may be inter-correlated, a multivariate analysis was performed, and only previous acute ankle injury was found to be a significant risk factor for a new acute ankle. The importance of this risk factor increases with number of previous injuries (test of trend, P=0.001), and seems to decrease with time since the last injury (test of trend, P=0.06). A complete listing of the results may be seen in tables 1, 2 and 3 in Paper II.

Several authors have found previous ankle injuries to be a significant risk factor for new injuries, both in male football (Ekstrand & Gillquist, 1983a; Tropp et al., 1985; Árnason et al., 2004b; Kofotolis et al., 2007) and among male athletes in other sports (Bahr & Bahr, 1997; McKay et al., 2001; Tyler et al., 2006; McGuine & Keene, 2006; McHugh et al., 2006). The study by Árnason et al. (2004b), which is the only other large-scale study using a multivariate approach to examine several different factors, found previous ankle injury to be the only significant risk factor for a new injury to the same ankle in a large cohort study investigating risk factors for football injuries, the same way as we did. In the same study, lateral instability and a positive anterior drawer test were correlated with previous injury. In contrast to these findings, Trojian and McKeag (2006) and Hägglund et al. (2006) did not find a history of previous ankle injury to be associated with future ankle sprains. However, a limited number of acute ankle injuries were included in these studies (Árnason et al., 2004b; Hägglund et al., 2006; Trojian & McKeag, 2006).

Ankle injuries have been prevented effectively through neuromuscular training, either on a balance board or balance mat, in football (Tropp et al., 1985; Árnason et al., 1996) and in other sports (Bahr et al., 1997; Garrick & Requa, 2005; Olsen et al., 2005; McHugh et al., 2007). Therefore, it seemed reasonable to suggest that a similar exercise could be used as a screening test to identify players at risk. The literature is limited on the topic, and only two publications have looked at whether single leg balance tests can predict risk of new ankle injuries in male football (Trojian & McKeag, 2006; McHugh et al., 2006). Trojian and McKeag (2006) found a predictive value of balance tests, while McHugh et al. (2006) did not. However, several publications looking at balance, measured in different ways, as a predictor of increased risk of injury among male athletes do exist from other sports (McGuine et al., 2000; Willems et al., 2005; Wang et al., 2006; Hrysomallis et al., 2007). In the present study, none of the balance tests, on the floor or a balance mat, turned out to be significant predictors. There are several potential explanations for this apparent discrepancy. First, even though this study is one of the largest cohort studies on risk factors for injuries to date, with as many as 56 acute ankle injuries, the statistical power is limited for multivariate tests. Nevertheless, the strength of the candidate risk factors studied does not indicate that any of these would be helpful as screening tools. Second, the results indicate that the intertester reliability for the balance tests used is low, with kappa values of 0.40 and 0.19. This shows that the same player will not necessarily be scored the same way from two different tests of the same ankle, a factor which clearly influences the ability to identify players with reduced ankle control. Third, the floor test has a ceiling effect in this player population, with 97.4% of the subject obtaining a normal or supranormal test score. Because we suspected that this test could be too easy, we also included the balance mat test. For this, the test distribution was better (34.6%, 34.5% and 25.8% in categories 2, 3 and 4, respectively), and the main problem may be that the balance mat test is inconsistent, as indicated by the low kappa value. Also, data from Australian football suggest that balance deficits do not necessarily persist among previously injured athletes (Hrysomallis et al., 2005). To identify athletes at risk based on tests measuring balance and ankle control, we clearly need to develop new methodology with better test properties and reliability.

Using multivariate methods where we have controlled for significant risk factors as well as player exposure, this study confirms the consistent finding from previous studies that players with a history of ankle sprains are at increased risk (Ekstrand & Gillquist, 1983a; Tropp et al., 1985;

Árnason et al., 2004b; Kofotolis et al., 2007). The high risk period is the first 6 months after a previous injury, as also shown in a study among volleyball players (Bahr & Bahr, 1997). It seems reasonable to recommend that injured players complete a program of balance training on a wobble board for 10 weeks, as first described by Tropp et al. (1985), and that they use tape or a brace during high risk activities until their rehabilitation is completed (Ekstrand et al., 1983a; Tropp et al., 1985). Studies have shown that taping (Ekstrand et al., 1983a; Tropp et al., 1985) or using an orthotic device (Surve et al., 1994) prevents reinjury in athletes with a history of ankle sprain, but that both methods have much greater effect on previously injured players. This may be due to the manner in which taping and braces apparently work; that is, they improve the ability of the ankle to react quickly to an inversion stress, but not as a passive mechanical support. Following these guidelines may prevent the athlete from entering a vicious circle with repeated ankle sprains and chronic ankle instability problems.

Risk factors for knee injuries (Paper III)

Univariate analyses revealed that the KOOS sub scores "Pain" and "Function in daily living" were potential leg-dependent risk factors for acute knee injuries. Also, the clinical examination was a potential means of identifying players at risk; any positive finding at clinical examination, deviations from the normal knee axis and flexion contraction in range of motion testing were candidate factors. As for the specific knee testing, a positive varus stress test in full extension and in 30 degrees of flexion were potential predictors of increased risk. None of the player-dependent factors tested were significantly associated with risk of knee injury. However, no significant risk factors for new acute knee injuries were identified in the final multivariate analysis when the candidate factors were included. Out of a total of 1016 cases, the final multivariate analysis was based on 812 cases after cases with missing data were excluded.

The literature on risk factors for acute knee injuries among male football players is limited. A history of previous knee injury seems to be the most important risk factor for new injuries, both in male football (Ekstrand & Gillquist, 1983a; Árnason et al., 2004b; Hägglund et al., 2006) and among male athletes in other sports (Taunton et al., 2003; Meeuwisse et al., 2003; Yung et al., 2007). Árnason et al. (2004b) found previous knee injury to be the only significant risk factor for a new injury to the same knee in a large cohort study investigating risk factors for football injuries. In the same study, increased valgus laxity was associated with a history of previous injury. In a recent study among female youth football players previous injury was the only risk factor identified (Steffen et al., 2008a). These results are in contrast to the present study, where no association was seen between previous injury and new injuries in the categorical analysis.

However, there is a trend suggesting an association between injury risk and the number of self-reported previous knee injuries. Also, as we observed a highly significant correlation between any pathological finding on the clinical knee examination and increased injury risk, this represents indirect evidence to the same association. It could be that the most serious injuries, causing abnormalities which could be detected through the clinical exam, do predispose a player for new injuries. Still, the overall findings in this study indicate that the strength of the candidate risk factor previous injury is low and alone it cannot be used to identify and target high-risk players with preventive measures, at least not in this player population.

Although one should think that significant injuries are easily remembered, there are indications in the literature that the number of previous injuries or even injury location may be difficult to report correctly (Gabbe et al., 2003). Therefore, recall bias may be a significant factor (Árnason et al., 2004b; Steffen et al., 2008a). A recent study from Swedish elite football bypassed this problem by including prospective data collected over two consecutive seasons. They showed that an injury in the first season increased injury risk during the subsequent season (Hägglund et al., 2006).

Of the other potential risk factors suggested from studies in different sports, age groups or among female athletes in the literature (gender (Lindenfeld et al., 1994; Ahmad et al., 2006; McLean et al., 2007), age (Backous et al., 1988; Lindenfeld et al., 1994; Östenberg & Roos, 2000), slow reaction time (Taimela et al., 1990), personality factors (Taerk, 1977; Lysens et al., 1989; Taimela et al., 1990; Junge et al., 2000), disobeying fair play (Roberts et al., 1996; Peterson et al., 2000), playing position (Lindenfeld et al., 1994), quadriceps-to-hamstring strength ratio (Ahmad et al., 2006), landing technique (Hass et al., 2005; McLean et al., 2007), fatigue (McLean et al., 2007), neuromuscular control of the knee (Hewett et al., 2005) or trunk (Zazulak et al., 2007), history of low back pain (Zazulak et al., 2007) and general joint laxity (Baumhauer et al., 1995; Östenberg & Roos, 2000; Beynnon et al., 2001; Myer et al., 2008), only age was tested in this study and this did not prove useful. It should be noted that knee joint laxity was tested through static stress tests; this should not be confused with the dynamic valgus pattern associated with non-contact ACL injuries among female athletes (Hewett et al., 2005). We also included maximal jump and sprint test in this study because we hypothesized that players generating the largest forces when running and cutting and in landings could be at greater risk of knee injury. Moreover, in the present study different self-reported measures of body size (height, weight, BMI) were not associated with increased injury risk, which is in accordance with previous risk factor studies (Árnason et al., 2004b; Steffen et al., 2008c).

Risk factors for hamstring injuries (Paper IV)

Univariate analyses revealed previous acute hamstring injury (yes/no), total HaOS function score and the four of five sub-scores symptoms, pain, function in sports and quality of life as potential leg-dependent risk factors for hamstring injuries. Of the player-dependent factors, age and player position were identified as potential predictors of increased injury risk. The multivariate analysis found history of previous acute hamstring injury to be a significant risk factor for new hamstring injuries (adjusted OR: 2.19 [1.19-4.03], P=0.01). Out of a total of 1016 cases, the final multivariate analysis was based on 893 cases after cases with missing data were excluded.

Several authors have found previous acute hamstring strains to be a significant risk factor for new injuries, both in male football (Árnason et al., 2004b; Hägglund et al., 2006) and among male athletes in other sports (Gabbe et al., 2005; Gabbe et al., 2006). This is in correspondence with the present findings, showing that the injury risk is doubled among previously injured players. Although the results were not significant, the risk seems to increase gradually with the number of previous injuries and decrease with time since the previous injury.

The Nordic hamstring exercise is the best documented preventive exercise for hamstring injuries (Askling et al., 2003; Árnason et al., 2008), and has been shown to increase muscle strength and does not require advanced equipment (Mjølsnes et al., 2004). It therefore seems reasonable to suggest that all football players, especially players with a history of previous hamstring injury, use this exercise regularly (Askling et al., 2003). Because the compliance with preventive exercises is low (Myklebust et al., 2003) and (Paper I) , we recommend that they are done during team practices under supervision.

Strength deficits or imbalances have been suggested to increase hamstring injury risk (Croisier et al., 2008), although the relationship between advanced isokinetic testing and injury risk is not fully resolved (Bennell et al., 1998). Isokinetic tests have been criticized for their lack of specificity and the fact that eccentric strength training can prevent strains made us hypothesize that the Nordic hamstring exercise could be used as a simple screening test to identify players at risk. However, there was no association between the test and injury risk. The most likely explanation for this is that the reliability for the Nordic hamstring strength test is low, with a kappa value of only 0.24. This shows that the same player will not necessarily be scored the same way on two separate tests, a factor which clearly influences the ability to identify players with poor hamstring strength. It could also be that the cut-off angle was set too high or low. Another factor may be that the test examines the combined strength of both sides, which means that side-to-side imbalances or weakness related to previous injury on one side therefore will be difficult to detect.

In addition to previous injury, Árnason et al. (2004b) found age to be a significant risk factors for a new strain injury, independent of injury history. In the present study, age was associated with injury risk in the univariate analysis but not in the multivariate analysis.

Among other potential risk factors mentioned in the literature, reduced flexibility has been suggested as a risk factor for hamstring strains (Witvrouw et al., 2003; Bradley & Portas, 2007). It has also been shown that football players are less flexible than a control group (Ekstrand & Gillquist, 1982) and that football players often do not pay sufficient attention to stretching exercises (Ekstrand et al., 1983b; Inklaar, 1994b; Árnason et al., 1996; Hawkins & Fuller, 1998). A study from Australian rules football examining a simple way of measuring hamstring flexibility – the toe touch test – did not find it useful as a predictor of increased risk of hamstring strains in Australian rules football players (Bennell et al., 1999). The test used to measure hamstring muscle length in this study has been used in different studies (Fredriksen et al., 1997; Árnason et al., 2004b). Árnason et al. (2004b) did not find hamstring muscle length to be a significant predictor of injury risk, which is in correspondence with the present findings. The coefficient of variation for the measurements from the passive knee extension test in this study was 9%, which means that the accuracy of the test is quite good. In other words, it seems that there is no association between hip flexion range of motion flexibility and hamstring injury risk, which may explain why stretching programs do not seem to influence injury risk (Thacker et al., 2004; Árnason et al., 2008).

From a biological perspective, it seems reasonable to suggest that explosive athletes with a dominant fast muscle fiber type would be more prone to sustain strain injuries. In this study, however, neither the 40 m sprint test nor the counter movement jump test was associated with injury risk.

We did not record whether injuries resulted from contact or non-contact. Injury resulting from contact with other players is rarely the case with hamstring strains. In fact, a study from English professional football non-contact injuries were found to be responsible for 91% of the hamstring injuries (Woods et al., 2004).

In this study, overuse injuries where no time-loss had occurred were also included as hamstring injuries. Because MRI or ultrasound examinations were not readily available, we did this to include small repeated strain injuries, as some players still elect to play despite discomfort in the posterior thigh. We cannot be sure that all of these represented true strain injuries to the hamstring muscles, but a separate statistical analysis using solely acute time-loss injuries as end point (data not shown) did not change the main findings.

Risk factors for groin injuries (Paper V)

Univariate analyses revealed the following potential leg-dependent risk factors for groin injuries; previous acute groin injury, total GrOS and GrOS sub scores "symptoms", "soreness" and "pain" and the clinical tests pain at external rotation in the hip joint and reduced range of motion for external rotation, pain at functional testing of the rectal abdominal muscles, weak adductor muscles determined clinically, pain at functional testing of the iliopsoas muscles and weak iliopsoas muscles determined clinically. Of the player-dependent factors, age and counter movement jump test were significantly associated with risk of groin injury. In cases where two of the potential leg-dependent risk factors were strongly intercorrelated ($p<0.05$), only the most clinically relevant test was included in the final multivariate analysis. This includes pain at external rotation in the hip joint and reduced range of motion for external rotation (intercorrelation $p=0.02$) (pain at external rotation chosen due to greater clinical relevance) and weak iliopsoas muscles determined clinically versus pain at functional testing (intercorrelation $p=0.02$) (weak iliopsoas muscles chosen because this was believed to be clinically more specific).

The multivariate analysis showed that previous acute groin injury (adjusted OR 2.60, 95% CI 1.10 to 6.11) and weak adductor muscles determined clinically (adjusted OR 4.28, 95% CI 1.31 to 14.0) were significant predictors of increased risk of groin injuries. Out of 1016 cases, the final multivariate analysis was based on 560 cases after cases with missing data were excluded.

Separate statistical analysis using acute time-loss injuries only was also carried out. The univariate analyses identified the 40 m sprint test, counter movement jump test and level of play as additional potential player-dependent risk factors, while previous acute groin injury, GrOS and functional testing of the abdominal muscles were identified as potential leg-dependent risk factors. A multivariate analysis based on acute time-loss injuries only revealed 40 m sprint test result (adjusted OR 2.03, 95% CI 1.06 to 3.88, $p=0.03$) and functional testing of the abdominal muscles (adjusted OR 15.5, 95% CI 1.11 to 217, $p=0.04$) as significant risk factors.

Previously injured players have more than twice as high risk of sustaining a new groin injury, while players with weak adductor muscles have a four times higher injury risk. Previous injury seems to be the most consistent intrinsic risk factor identified in the literature. A systematic review examining risk factors for acute muscle strains in different sports found previous injury to be a strong predictor of muscle strain injury (Emery, 1999). In a multivariate analysis in the largest cohort study to date in male football, previously injured players were found to have more than a seven-fold increased risk of sustaining new groin injuries compared with uninjured controls (Árnason et al., 2004b). A study from Swedish elite football also found previous injury to the same leg to be a significant risk factor (Hägglund et al., 2006). These findings are also consistent with studies from other sports with high demands on the groin area (Maffey & Emery, 2007). The results from the present study are in accordance to these findings. As underlined earlier, adequate rehabilitation and preventing the first injury should be a high priority also for groin injuries. To accomplish this, the best method may be strength exercises. While a passive physical therapy programme of massage, stretching and modalities was ineffective in treating chronic groin strains, Hölmich et al (1999) demonstrated that an 8- to 12-week active strengthening programme, consisting of progressive resistive adduction and abduction exercises, balance training, abdominal strengthening and skating movements on a slide board, was effective in treating chronic groin strains. Our own intervention (Paper I) using a modified, shortened version of this programme did not find a preventive effect . However, due to poor compliance it is not possible to say whether the shortened programme would have been effective, if completed as prescribed. Also, in professional ice hockey adductor strengthening exercises reduced the number of groin injuries (Tyler et al., 2002).

The other main observation in the present study was that players assessed to have weak adductors in the clinical examination had four times the injury risk of players with normal strength. No publications exist from male football on the topic, but in a study from male elite ice hockey, significantly lower adductor strength was found among injured players (Tyler et al., 2001). However, in contrast to the clinical examination, adductor strength measured by a handheld dynamometer was not significantly associated with risk of injury. Still, the coefficient of variation for this test of 19.6% indicates that inter-test reliability was limited.

Hip and groin injuries are reported to often occur in sports involving side-to-side cutting, quick accelerations and decelerations, and sudden directional changes (Morelli & Weaver, 2005). Strength imbalances between the propulsive muscles and the stabilizing muscles of the hip and pelvis (Garrett, Jr. et al., 1987) and between the synergistic abductors and adductors have been suggested as risk factors for groin injuries (Maffey & Emery, 2007). Also, delayed contraction of the transversus abdominis (Cowan et al., 2004), as a measure of reduced core stability, has been suggested in the literature. Unfortunately, based on the tests performed in this study, these hypotheses cannot be addressed.

Neither this nor previous studies (Tyler et al., 2001; Árnason et al., 2004b) have identified adductor length as a risk factor for groin injury in football, and stretching programs do not seem to influence injury risk (Thacker et al., 2004). A study from Belgian elite football found no predictive value of adductor flexibility measurements (Witvrouw et al., 2003). Still, Árnason et al. (2004b) found decreased range of motion in hip abduction to be a significant risk factor for groin injuries, which is in contrast with the present findings. In the present study (Paper V), however, hip range of motion was only examined clinically.

Age and experience have been suggested as risk factors in elite ice hockey (Emery & Meeuwisse, 2001). The present study found these factors to be strongly associated with injury risk in the univariate, but not in the multivariate analysis. This is in accordance with previous studies from football (Árnason et al., 2004b) and other sports (Orchard et al., 1998; Emery & Meeuwisse, 2001).

It seemed reasonable to hypothesize that explosive athletes with a dominant fast-twitch muscle fiber type would be more prone to strain injuries. However, in this study neither the 40 m sprint test nor the counter movement jump test result was associated with injury risk in the main analysis. This is in accordance with Árnason et al (2004b), who found no predictive effect of jump tests. However, it should be noted that correspondingly to the hamstring analyses, overuse injuries where no time-loss had occurred were also included in our definition of groin injuries. Still, using acute time-loss injuries only as the end point identified the 40 m sprint test and functional testing of the abdominal muscles as significant risk factors. This could indicate that the risk for acute injuries is increased among "explosive" players, and that previous injury is less important as risk factor for new acute injuries. However, as this analysis is based on only 22 acute time-loss injuries it needs to be interpreted with caution.

Screening

In regards of the predefined high-risk and low-risk groups, the incidence was lower in the LR control group than both other groups (RR: 0.65 vs. the HR intervention group, 95% CI: 0.51 to 0.85; RR: 0.61 vs. the HR control group, 95% CI: 0.48 to 0.79) (Paper I). During the season, 45.8% of the players in the LR control group (55 of 120 players) sustained one or more injuries, compared to 58.5% in the HR control group (114 of 195 players; P=0.029 vs the LR control group; chi square test) and 59.1% in the HR intervention group (114 of 193 players; P=0.90 vs the HR control group). This implies that an overall, unspecific identification of high-risk athletes can be done. The sensitivity of this screening was 85%, while the specificity using our predefined criteria was 28%. The positive and negative predictive values were 39% and 78%, respectively. However, the high risk groups (HRi and HRc) have a considerable amount of injuries. In order to target preventive training to the players with highest risk of injury, the information from the cohort studies (Papers II-V) must be considered.

Screening for ankle injury risk (Paper II). A history of previous acute ankle injury proved to be the only significant risk factor for new injuries to the same ankle in this prospective cohort study.

Players with multiple and/or recent injuries are at a high risk. For practical use, the sensitivity of previous injury (yes or no) as a predictor for new ankle sprains was 74%, which means 74% of the players who sustained an ankle injury during the season had a history of ankle sprains. However, the positive predictive value was only 6%, which means that only 6% of previously injured players suffered a new ankle sprain during the season. This figure increases gradually with the number of previous injuries to 10% if the player has had five or more previous acute ankle injuries. The same is the case if there was a history of a recent sprain, i.e. during the last 6 months (9%). Based on these results, it does not seem possible to target preventive measures based on a history of ankle sprains alone. The results from this study also show that additional information such as balance tests, player interviews or clinical examination does not increase our ability to identify players at risk.

Knee (Paper III). No significant predictors of knee injury risk were found in this study. More advanced tests requiring advanced laboratory equipment have been used in studies on risk factors for ACL injuries among female athletes (Hewett et al., 2005; Ahmad et al., 2006; Zazulak et al., 2007), and an association has been demonstrated with deficits in neuromuscular control of the trunk, biomechanical measures of neuromuscular control and valgus loading of the knee, and high quadriceps-to-hamstring ratio. However, the present findings, based on the simple screening methods examined, indicate that it is not possible to screen and identify players with high risk of knee injuries. In regards of the identification of players with self-reported previous ACL injuries, the sensitivity and specificity for the Lachman test were 36% and 99% in the present study.

Hamstring (Paper IV). For practical use, the sensitivity of previous injury (yes or no) as a predictor for new hamstring strains was 51%, which means 51% of the players who sustained a hamstring injury during the season had a self-reported history of acute hamstring strains. The specificity of previous injury (yes or no) as a predictor for new hamstring strains was 70%. The positive predictive value was 10%, which means that 10% of previously injured players suffered a new hamstring injury during the season. The negative predictive value was 95%. The sensitivity decreased gradually with the number of previous injuries to 11% for more than five previous hamstring strains, while the corresponding figures for the positive predictive value increase gradually to 21%. When looking at the time since injury, it seems as though an injury during the last 12 months is as important as during the last 6 months, both with a positive predictive value of 14%, while the sensitivity was 14% and 28% for the last 6 and 12 months, respectively. The sensitivity even increases for the category “previous hamstring strain during the last two years” to 42%, with a positive predictive value of 13%, until both values decline when looking at the category of more than two years since injury. This is in accordance with the findings by Árnason et al (2004b).

Groin (Paper V). For practical use, the sensitivity of previous injury (yes or no) as a predictor for new groin strains was 55%, which means that 55% of the players who sustained a groin injury during the season had a self-reported history of acute groin strains. The specificity of previous injury (yes or no) as a predictor for new groin strains was 66%. The positive predictive value was 9%, which means that 9% of previously injured players suffered a new groin injury during the season. The negative predictive value was 96%. The sensitivity decreased with number of previous injuries to 7% for more than five previous acute groin strains, while the corresponding figures for the positive predictive value only increases to 10%, which implies that being previously injured (if only once) is relatively more important in regards of risk of new injuries than having had several previous acute groin strains which did not significantly increase the predictors value. When looking at time since injury, also here, it seems as though being previously injuried is the most important distinction, rather than if the injury is recent or not. The sensitivity and positive predictive values are 15% and 9% for previous injury during the last 6 months and 18% and 9% when the injury is more than 2 years ago, respectively. When looking at the second significant risk factor for new groin injuries, weak adductors as determined clinically, the sensitivity is 15% and the positive predictive value is 16%.

Reliability testing (Papers II-V)

Ankle (Paper II). Inter-test reliability for the categorical variables, computed using kappa statistics, were 0.40 and 0.19 for balance tests on the floor and mat, respectively. For the clinical examination, kappa values were 0.45 (anterior drawer), 0.84 (foot type), 0.91 (standing rearfoot alignment), 1.00 (hallux position), and 1.00 (toe deformity).

The intertester reliability for especially the balance tests used was low. This shows that the same player will not necessarily be scored the same way from two different tests of the same ankle, a factor which clearly influences the ability of these tests to identify players with reduced ankle control.

Knee (Paper III). Inter-test reliability for the clinical examination was 1.00 for all tests examined; Lachman, posterior drawer, varus stress test in extension, varus stress test in 30 degrees of flexion, valgus stress test in extension) and valgus stress test in 30 degrees of flexion. These are optimal inter-test reliability and means that the same knee was scored the same when examined for the same test by two different physicians or physiotherapists in the study.

Hamstring (Paper IV). Inter-test reliability was 0.24 for the Nordic hamstring strength test, which indicates poor reliability. Hence, it influences the test's ability to identify players with poor hamstring strength.

The coefficient of variation for the continuous variable hamstring muscle length was 9.1%. In other words, the accuracy of the test is quite good.

Groin (Paper V). The coefficient of variation for the continuous variable adductor strength was 19.6%, which is poor.

Screening for injury risk - Discussion

Although the intervention was ineffective, this study demonstrated that players who potentially had the most to gain from preventive exercises could be identified. The risk of injury was approximately twice as high among athletes with a history of previous injury and/or who reported reduced function. This identification was achieved through the use of a simple questionnaire only, and the addition of more elaborate functional tests did not increase the predictive value of the screening (Papers II-V). The rationale for the approach used, employing a self-completed questionnaire, was the potential for expanding the range of application of the athlete screening process. The increased risk associated with a history of previous injury and reduced function also has other implications. One is that preventing the first injury should be a high priority to keep players from entering the vicious circle of repeated injuries to the same body part. The most likely explanation for previous injury being such a consistent risk factor for reinjuries, is that the joints or muscles in question are not fully restored structurally and/or functionally. Based on this, it seems reasonable to suggest that one thing teams can do, even at lower levels of play, is to focus on improving rehabilitation after injury and implementing adequate return-to-play guidelines, such as demonstrated by Soligard et al. (2008). Players with reduced function after previous injury should undergo a structured rehabilitation program until full function is established. However, it remains to be proven whether this would reduce injury risk significantly. The present study (Paper I) also shows that this cannot be left to the players themselves; adequate supervision is necessary.

As stated in the introduction, history has shown that achieving good compliance with preventive exercises is a challenge (Myklebust et al., 2003). This was also the case in the present intervention study (Paper I). There is a wide gap between research and "real-world" implementation, which has taught us that seemingly effective preventive exercises are actually just effective when they *both* reduce injuries *and* are found interesting and fun enough to be carried out by the players. One aspect in trying to achieve this goal of developing meant-to-be preventive programs is to target the players in the most need of such. If a player is at high risk of sustaining for instance a groin injury, it is probably much more important for that player to carry out groin preventive exercises thoroughly than lots of general preventive exercises, and consequently less for the groin. This thesis confirms that screening in football medicine can be done (Paper I). Players with significantly increased risk of injury can be identified through self-reporting of history of previous injuries and function scores. The risk factor studies (Paper II-V) aid us further in the identification of the players with even higher risk of new injuries. However, it seems as though additional information and testing is of limited use; previous injury is generally (even though it did not prove useful in relation to knee injuries in paper III) the most important risk factor for new injuries, which is in concordance with previous studies in senior male football (Árnason et al., 2004b; Hägglund et al., 2006; Hölmich et al., 2009). This may implicate that sports medicine practitioners should emphasize firstly getting those players to carry out preventive exercises. Down the road, the ultimate goal would be to develop self-administered screening, maybe in the form of a web-based solution, which would fulfil one of the main goals of this thesis – making sports medicine available to every footballer, not just the elite players. Unfortunately, however, the positive predictive values of the identified risk factors for ankle, hamstring and groin injuries are only approximately 10%. This means that targeting preventive training to all players who will sustain a new injury is not possible – we can only identify approximately 10% of these players through our screening methods.

Interestingly, the results from the main screening performed in Paper I, investigating the predefined high-risk and low-risk criteria (previous injury last year or function score < 80% in the ankle, knee, hamstring or groin) show a better test reliability. The sensitivity and positive predictive value of this screening was 85% and 39%, respectively, which means that 85% of the players who sustained a new ankle, knee, hamstring or groin injury in the subsequent season were predefined as high-risk athletes, and more importantly that as many as 39% of the players who were thought to have an increased injury risk actually did sustain a new injury. Also, the relatively high negative predictive value means that 78% of the players assigned to the low-risk group did not sustain a new ankle, knee, hamstring or groin injury in the following season. This implies that an overall, unspecific identification of high-risk athletes can be done. However, one has to bear in mind that as many as 76% of the players fulfilled the high-risk criteria. For the screening to have important relevance, the number of players identified as having low injury risk would optimally be much higher than 24%.

Nevertheless, we suggest that information on previous recent injuries and reduced function in the ankle, knee, hamstring and groin is taken into account when injury risk is considered. However, even though a significant number of high risk players can be identified in this way, we suggest that all players should carry out the exercises in order to reduce the risk for all players who would sustain an injury in the following season. As discussed above, screening for injury risk cannot free some players from training preventive exercises; we can not say for sure that a player without for instance history of previous injury will not sustain an injury. Still, the present results aid us in identifying high-risk players who definitely should carry out preventive training programs.

Limitations

Methodological issues

In regards to the mechanism of injury, in the context of hamstring strains, intrinsic factors seem more predictive of injury than extrinsic ones (Orchard, 2001), which is why we had intrinsic risk factors as a focus area in the present study. Also, no registration of contact and non-contact injuries was made in this study. Contact injuries represent a much more heterogeneous group with respect to the reasons for injury and most of the potential and known intrinsic risk factors for injuries in male football are thought to apply best to non-contact injuries. However, to a player, the important issue is whether he is injured or not, and in this study the main goal was to look at simple ways of measuring potential risk factors for injuries, not injury mechanisms. Hence, the injury reporting form was simplified to possibly improve compliance from the physiotherapists. The risk of sustaining contact injuries is considerable in football, but one cannot eliminate the risk of contact and thereby contact injuries in football, and the risk factors tested in this study were therefore evaluated independently of contact or non-contact mechanisms. While contact with another player in the injury situation may play a role in a significant percentage of sprain injuries to the ankle and knee, contact is less dominant in strain injury mechanisms (Woods et al., 2004). If there were a number of contact injuries among the injuries recorded, these would presumably serve to dilute the effect of the risk factors studied. However, we cannot correct for this, because the mechanism of injury in each case was not known.

Exposure registration

We had to rely on the coaches for the exposure registration. We had no way to check their figures, but there should be no reason to misreport. If a game or practice session was missed, it would affect all players on the team, which is unlikely to influence the analysis regarding any specific risk factor or the intervention outcome.

Study size

The risk factor studies are among the largest cohort studies on risk factors for injuries to date, with as many as 56, 61, 76 and 61 ankle, knee, hamstring and groin injuries respectively.

Nevertheless, the statistical power is limited for multivariate tests. Still, the strength of the candidate risk factors studied does not indicate that any of these would be helpful as screening tools. As pointed out by Bahr & Holme (2003) in their review, to detect moderate to strong associations 20–50 injury cases are needed, whereas small to moderate associations would need about 200 injured subjects. However, for a risk factor to be clinically relevant with sufficient sensitivity and specificity, strong associations are needed. The objective of risk factor research is to identify clinically relevant, not just statistically significant factors. In this context, several of the factors that were found to be statistically significant in the univariate analysis are unlikely to be clinically relevant. Our conclusions are therefore based solely on the results of the final multivariate analysis.

Validity for other sports, levels of play, ages or females

This study was carried out among subelite male football players, and should not be extrapolated to other sports, females, youth players or other levels of play.

Perspectives

Prevention of injuries in football - Laws of the game

As described in this thesis, injuries in football constitute a major concern for society, teams and the individual athlete. Even though the intervention in Paper I did not reduce injuries, indications are that preventive exercises can reduce injury risk. No focus was made on contact injuries in the present study. It is believed that non-contact injuries are easiest to reduce through such exercises. Despite an optimistic attitude in football medicine and, in time, development of even more effective preventive exercises, some injuries in football will always remain, such as those due to foul play. In regards to injury prevention, an issue that has not been addressed in this thesis is therefore a more superior point of attack; maybe changes in the laws of the game are needed. Recently, an example of such a change, where players are given a red card when using elbows in heading duels has been implemented with success (Dvorak, 2009). However, du to the limitation of the studies.this issue will not be discussed here.

Converting research to practice

Another challenge in prevention of injuries is converting the results from encouraging injury preventing studies into life. It seems as advances in the science of injury prevention have not always led to advances in practice (MacKay & Vincenten, 2009); effective approaches are not always adopted, or when adopted and transferred from one setting to another, they do not always achieve expected results. For interventions that have been efficacious in controlled trials to possibly matter in terms of public health impact, they also need to be widely adopted and sustained (Finch & Donaldson, 2009). Oslo Sports Trauma Research Center, recently awarded a FIFA Medical Centre of Excellence, has taken this responsibility and is part of a serious engagement in research (www.ostrc.no). This has resulted in, inter alia, a separate area of effort ("Skadefri", www.skadefri.no) where players can see how to perform preventive exercises. But that is not enough; efforts are also paid in reaching players with the message. As demonstrated by Twomey et al (2009), there is still a long way left in order to convert research results into practice. In a survey among coaches in Australian football, they found that only one-third believed that balance training had some importance for injury prevention, despite accumulating scientific evidence to support it. They concluded that current training sessions do not give adequate attention to the development of skills most likely to reduce the risk of lower limb injury in players. There was therefore a need to improve the translation of the latest scientific evidence about effective injury prevention into coaching practices. Also a study from football indicated that there was a need for wider education of players in current injury prevention strategies (Hawkins & Fuller, 1998).

Mahler and Donaldson (2010) recently questioned if currently known, but moderately evidence-based, prevention strategies are effective only if applied in a systematic and controlled way. Despite encouraging sports- or injury-specific interventions (Aaltonen et al., 2007), little data are available to show significant reduction of sports injuries over longer periods of time or in larger populations in "real-world" implementation settings (Mahler & Donaldson, 2010). On a general injury preventive basis, several authors have questioned if difficulties of translating research findings from the controlled environment of the research setting to the more complex environment of sports setting cause prevention strategies to be improperly implemented (Glasgow et al., 2003; Finch & Donaldson, 2009; MacKay & Vincenten, 2009). At least, from the present results, it seems as insufficient follow-up of effective interventions diminishes the chance of positive results. Systematic and controlled implementation may be necessary (Soligard et al., 2008).

Prevention at the top of it's game?

An interesting finding was revealed when looking at The Swiss National Injury Registry, which includes longitudinal data on sports injuries based on insurance claims; almost no change in the incidence of sporting injuries has been observed between 1998 and 2005 (39.7 $\pm$ 0.17 injuries/1000 inhabitants/year). However, almost no significant injury preventive interventions were introduced in relation to this period. Also, when comparing the injuries of young sportspeople with injuries in the general, age and geographically adjusted, population there was no statistical difference (Mahler & Donaldson, 2010). Mahler and Donaldson (2010) have therefore questioned if there might actually be a "threshold" incidence of injuries below which it might be difficult to go, hence wondering if injury prevention efforts have contributed significantly to performance enhancement in sports, while injuries have stayed relatively constant over time. Given the relatively low injury incidence in this thesis, such a "threshold hypothesis" may add partial explanation to the believed to be main reason for the negative results from intervention, the poor compliance.

However, as indicated in this thesis, there is still a potential for prevention of injuries in football. Just recently, a study showed that injury incidence increases when recovery time is insufficient (Dupont et al., 2010).

Conclusions

1. Players with an increased injury risk were identified through a comprehensive questionnaire. The positive and negative predictive values of this screening were 39% and 78%, respectively.
2. The targeted intervention did not affect injury risk. Due to low compliance it is difficult to conclude about the true effect of the training programs.
3. Previous ankle injury was the only significant predictor for new acute ankle injuries. The risk increases with the number of previous injuries and is highest during the first 6 months after injury.
4. None of the potential leg- or player-dependent risk factors studied could be used to predict increased risk of knee injury.
5. A history of previous acute hamstring injury is a significant risk factor for new hamstring injuries. Previously injured players have more than twice as high risk of sustaining a new injury.
6. A history of a previous acute groin injury and weak adductor muscles were found to be significant risk factors for new groin injuries. Previously injured players have a more than twice as high risk of sustaining a new groin injury, while the risk is four times higher in players with weak adductor muscles.

References

Aaltonen, S., Karjalainen, H., Heinonen, A., Parkkari, J., Kujala, U. M., (2007). Prevention of sports injuries: systematic review of randomized controlled trials. Arch.Intern.Med. 167, 1585-1592.

Agre, J. C., (1985). Hamstring injuries. Proposed aetiological factors, prevention, and treatment. Sports Med. 2, 21-33.

Ahmad, C. S., Clark, A. M., Heilmann, N., Schoeb, J. S., Gardner, T. R., Levine, W. N., (2006). Effect of gender and maturity on quadriceps-to-hamstring strength ratio and anterior cruciate ligament laxity. Am.J.Sports Med. 34, 370-374.

Albright, J. P., Powell, J. W., Smith, W., Martindale, A., Crowley, E., Monroe, J., Miller, R., Connolly, J., Hill, B. A., Miller, D., ., (1994). Medial collateral ligament knee sprains in college football. Effectiveness of preventive braces. Am.J.Sports Med. 22, 12-18.

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

Andersen, T. E., Floerenes, T. W., Árnason, A., Bahr, R., (2004b). Video analysis of the mechanisms for ankle injuries in football. Am.J Sports Med 32, 69S-79S.

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

Andersen, T. E., Tenga, A., Engebretsen, L., Bahr, R., (2004c). Video analysis of injuries and incidents in Norwegian professional football. Br.J.Sports Med. 38, 626-631.

Árnason, A., Andersen, T. E., Holme, I., Engebretsen, L., Bahr, R., (2008). Prevention of hamstring strains in elite soccer: an intervention study. Scand.J.Med.Sci.Sports 18, 40-48.

Árnason, A., Engebretsen, L., Bahr, R., (2005). No effect of a video-based awareness program on the rate of soccer injuries. Am.J.Sports Med. 33, 77-84.

Árnason, A., Gudmundsson, A., Dahl, H. A., Johannsson, E., (1996). Soccer injuries in Iceland. Scand.J.Med.Sci.Sports 6, 40-45.

Árnason, A., Sigurdsson, S. B., Gudmundsson, A., Holme, I., Engebretsen, L., Bahr, R., (2004a). Physical fitness, injuries, and team performance in soccer. Med.Sci.Sports Exerc. 36, 278-285.

Árnason, A., Sigurdsson, S. B., Gudmundsson, A., Holme, I., Engebretsen, L., Bahr, R., (2004b). Risk factors for injuries in football. Am.J.Sports Med. 32, 5S-16S.

Árnason, A., Tenga, A., Engebretsen, L., Bahr, R., (2004c). A prospective video-based analysis of injury situations in elite male football: football incident analysis. Am.J.Sports Med. 32, 1459-1465.

Askling, C., Karlsson, J., Thorstensson, A., (2003). Hamstring injury occurrence in elite soccer players after preseason strength training with eccentric overload. Scand.J.Med.Sci.Sports 13, 244-250.

Backous, D. D., Friedl, K. E., Smith, N. J., Parr, T. J., Carpine, W. D., Jr., (1988). Soccer injuries and their relation to physical maturity. Am.J Dis.Child 142, 839-842.

Bahr, R., Bahr, I. A., (1997). Incidence of acute volleyball injuries: a prospective cohort study of injury mechanisms and risk factors. Scand J Med Sci Sports 7, 166-171.

Bahr, R., Holme, I., (2003). Risk factors for sports injuries--a methodological approach. Br.J.Sports Med. 37, 384-392.

Bahr, R., Krosshaug, T., (2005). Understanding injury mechanisms: a key component of preventing injuries in sport. Br.J.Sports Med. 39, 324-329.

Bahr, R., Lian, O., Bahr, I. A., (1997). A twofold reduction in the incidence of acute ankle sprains in volleyball after the introduction of an injury prevention program: a prospective cohort study. Scand J Med Sci Sports 7, 172-177.

Baumhauer, J. F., Alosa, D. M., Renström, A. F., Trevino, S., Beynnon, B., (1995). A prospective study of ankle injury risk factors. Am.J Sports Med 23, 564-570.

Bennell, K., Tully, E., Harvey, N., (1999). Does the toe-touch test predict hamstring injury in Australian Rules footballers? Aust.J.Physiother. 45, 103-109.

Bennell, K., Wajswelner, H., Lew, P., Schall-Riaucour, A., Leslie, S., Plant, D., Cirone, J., (1998). Isokinetic strength testing does not predict hamstring injury in Australian Rules footballers. Br.J.Sports Med. 32, 309-314.

Beynnon, B. D., Renström, P. A., Alosa, D. M., Baumhauer, J. F., Vacek, P. M., (2001). Ankle ligament injury risk factors: a prospective study of college athletes. J Orthop.Res. 19, 213-220.

Bjørneboe J, Bahr R, Andersen, T. E., (2010). Risk of injury on football turf in Norwegian professional football. British Journal of Sports Medicine, p. In press.

Bjørneboe J, Floerenes, T. W., Bahr R, Andersen, T. E., (2009). Injury surveillance in male professional football; is medical staff reporting complete and accurate? Scandinavian Journal of Medicine & Science in Sports, p. In press.

Bot, S. D., van, M. W., (1999). The effect of ankle bracing on athletic performance. Sports Med. 27, 171-178.

Bradley, P. S., Portas, M. D., (2007). The relationship between preseason range of motion and muscle strain injury in elite soccer players. J Strength.Cond.Res. 21, 1155-1159.

Brockett, C. L., Morgan, D. L., Proske, U., (2001). Human hamstring muscles adapt to eccentric exercise by changing optimum length. Med.Sci.Sports Exerc. 33, 783-790.

Brockett, C. L., Morgan, D. L., Proske, U., (2004). Predicting hamstring strain injury in elite athletes. Med.Sci.Sports Exerc. 36, 379-387.

Brooks, J. H., Fuller, C. W., (2006). The influence of methodological issues on the results and conclusions from epidemiological studies of sports injuries: illustrative examples. Sports Med. 36, 459-472.

Caraffa, A., Cerulli, G., Projetti, M., Aisa, G., Rizzo, A., (1996). Prevention of anterior cruciate ligament injuries in soccer. A prospective controlled study of proprioceptive training. Knee.Surg.Sports Traumatol.Arthrosc. 4, 19-21.

Cowan, S. M., Schache, A. G., Brukner, P., Bennell, K. L., Hodges, P. W., Coburn, P., Crossley, K. M., (2004). Delayed onset of transversus abdominus in long-standing groin pain. Med.Sci.Sports Exerc. 36, 2040-2045.

Croisier, J. L., (2004). Factors associated with recurrent hamstring injuries. Sports Med. 34, 681-695.

Croisier, J. L., Forthomme, B., Namurois, M. H., Vanderthommen, M., Crielaard, J. M., (2002). Hamstring muscle strain recurrence and strength performance disorders. Am.J.Sports Med. 30, 199-203.

Croisier, J. L., Ganteaume, S., Binet, J., Genty, M., Ferret, J. M., (2008). Strength imbalances and prevention of hamstring injury in professional soccer players: a prospective study. Am.J.Sports Med. 36, 1469-1475.

Devlin, L., (2000). Recurrent posterior thigh symptoms detrimental to performance in rugby union: predisposing factors. Sports Med. 29, 273-287.

Drawer, S., Fuller, C. W., (2002). Evaluating the level of injury in English professional football using a risk based assessment process. Br.J.Sports Med. 36, 446-451.

Dupont, G., Nedelec, M., McCall, A., McCormack, D., Berthoin, S., Wisløff, U., (2010). Effect of 2 Soccer Matches in a Week on Physical Performance and Injury Rate. Am.J.Sports Med.

Dvorak, J., (2009). Give Hippocrates a jersey: promoting health through football/sport. Br.J.Sports Med. 43, 317-322.

Dvorak, J., Graf-Baumann, T., Peterson, L., Junge, A., (2000a). Football, or soccer, as it is called in North America, is the most popular sport worldwide. Am.J.Sports Med. 28, S1-S2.

Dvorak, J., Junge, A., (2000). Football injuries and physical symptoms. A review of the literature. Am.J.Sports Med. 28, S3-S9.

Dvorak, J., Junge, A., Chomiak, J., Graf-Baumann, T., Peterson, L., Rosch, D., Hodgson, R., (2000b). Risk factor analysis for injuries in football players. Possibilities for a prevention program. Am.J.Sports Med. 28, S69-S74.

Ekblom, B., (1986). Applied physiology of soccer. Sports Med. 3, 50-60.

Ekstrand, J., Gillquist, J., (1982). The frequency of muscle tightness and injuries in soccer players. Am.J.Sports Med. 10, 75-78.

Ekstrand, J., Gillquist, J., (1983a). Soccer injuries and their mechanisms: a prospective study. Med Sci Sports Exerc 15, 267-270.

Ekstrand, J., Gillquist, J., (1983b). The avoidability of soccer injuries. Int.J.Sports Med. 4, 124-128.

Ekstrand, J., Gillquist, J., Liljedahl, S. O., (1983a). Prevention of soccer injuries. Supervision by doctor and physiotherapist. Am.J.Sports Med. 11, 116-120.

Ekstrand, J., Gillquist, J., Moller, M., Oberg, B., Liljedahl, S. O., (1983b). Incidence of soccer injuries and their relation to training and team success. Am.J.Sports Med. 11, 63-67.

Ekstrand, J., Hägglund, M., Waldén, M., (2009). Injury incidence and injury patterns in professional football - the UEFA injury study. Br.J.Sports Med.

Ekstrand, J., Karlsson, J., (2003). The risk for injury in football. There is a need for a consensus about definitions of the injury and the design of studies. Scand J Med Sci Sports, pp. 147-149.

Ekstrand, J., Tropp, H., (1990). The incidence of ankle sprains in soccer. Foot Ankle 11, 41-44.

Emery, C. A., (1999). Does decreased muscle strength cause acute muscle strain injury in sport? A systematic review of the evidence. Phys Ther Rev, pp. 141-151.

Emery, C. A., Meeuwisse, W. H., (2001). Risk factors for groin injuries in hockey. Med Sci Sports Exerc 33, 1423-1433.

Emery, C. A., Meeuwisse, W. H., Hartmann, S. E., (2005). Evaluation of risk factors for injury in adolescent soccer: implementation and validation of an injury surveillance system. Am.J.Sports Med. 33, 1882-1891.

Engström, B. K., Renström, P. A., (1998). How can injuries be prevented in the World Cup soccer athlete? Clin.Sports Med 17, 755-68, vii.

FIFA - The History of Football, (2010). http://www.fifa.com/classicfootball/history/game/historygame1.html.

FIFA big count, (2007). FIFA big count 2006: 270 million people active in football. http://www.fifa.com/worldfootball/bigcount/index.html 31 May 2007.

Finch, C., Cassell, E., (2006). The public health impact of injury during sport and active recreation. J.Sci.Med.Sport 9, 490-497.

Finch, C. F., Donaldson, A., (2009). A sports setting matrix for understanding the implementation context for community sport. Br.J.Sports Med.

Fong, D. T., Hong, Y., Chan, L. K., Yung, P. S., Chan, K. M., (2007). A systematic review on ankle injury and ankle sprain in sports. Sports Med 37, 73-94.

Fredriksen, H., Dagfinrud, H., Jacobsen, V., Maehlum, S., (1997). Passive knee extension test to measure hamstring muscle tightness. Scand.J.Med.Sci.Sports 7, 279-282.

Fuller, C. W., Ekstrand, J., Junge, A., Andersen, T. E., Bahr, R., Dvorak, J., Hägglund, M., McCrory, P., Meeuwisse, W. H., (2006). Consensus statement on injury definitions and data collection procedures in studies of football (soccer) injuries. Clin.J.Sport Med. 16, 97-106.

Gabbe, B. J., Bennell, K. L., Finch, C. F., Wajswelner, H., Orchard, J. W., (2006). Predictors of hamstring injury at the elite level of Australian football. Scand J Med Sci Sports 16, 7-13.

Gabbe, B. J., Finch, C. F., Bennell, K. L., Wajswelner, H., (2003). How valid is a self reported 12 month sports injury history? Br.J.Sports Med. 37, 545-547.

Gabbe, B. J., Finch, C. F., Bennell, K. L., Wajswelner, H., (2005). Risk factors for hamstring injuries in community level Australian football. Br.J.Sports Med. 39, 106-110.

Garrett, W. E., Jr., Safran, M. R., Seaber, A. V., Glisson, R. R., Ribbeck, B. M., (1987). Biomechanical comparison of stimulated and nonstimulated skeletal muscle pulled to failure. Am.J.Sports Med. 15, 448-454.

Garrick, J. G., Requa, R., (2005). Structured exercises to prevent lower limb injuries in young handball players. Clin J Sport Med 15, 398.

Gilchrist, J., Mandelbaum, B. R., Melancon, H., Ryan, G. W., Silvers, H. J., Griffin, L. Y., Watanabe, D. S., Dick, R. W., Dvorak, J., (2008). A randomized controlled trial to prevent noncontact anterior cruciate ligament injury in female collegiate soccer players. Am.J.Sports Med. 36, 1476-1483.

Gissane, C., White, J., Kerr, K., Jennings, D., (2001). An operational model to investigate contact sports injuries. Med Sci Sports Exerc. 33, 1999-2003.

Glasgow, R. E., Lichtenstein, E., Marcus, A. C., (2003). Why don't we see more translation of health promotion research to practice? Rethinking the efficacy-to-effectiveness transition. Am.J.Public Health 93, 1261-1267.

Goldman, E. F., Jones, D. E., (2010). Interventions for preventing hamstring injuries. Cochrane.Database.Syst.Rev CD006782.

Greene, D. L., Hamson, K. R., Bay, R. C., Bryce, C. D., (2000). Effects of protective knee bracing on speed and agility. Am.J.Sports Med. 28, 453-459.

Greig, M., (2008). The influence of soccer-specific fatigue on peak isokinetic torque production of the knee flexors and extensors. Am.J.Sports Med. 36, 1403-1409.

Hägglund, M., Waldén, M., Ekstrand, J., (2003). Exposure and injury risk in Swedish elite football: a comparison between seasons 1982 and 2001. Scand.J.Med.Sci.Sports 13, 364-370.

Hägglund, M., Waldén, M., Ekstrand, J., (2005). Injury incidence and distribution in elite football--a prospective study of the Danish and the Swedish top divisions. Scand.J.Med.Sci.Sports 15, 21-28.

Hägglund, M., Waldén, M., Ekstrand, J., (2006). Previous injury as a risk factor for injury in elite football: a prospective study over two consecutive seasons. Br.J.Sports Med. 40, 767-772.

Hägglund, M., Waldén, M., Ekstrand, J., (2007). Lower reinjury rate with a coach-controlled rehabilitation program in amateur male soccer: a randomized controlled trial. Am.J.Sports Med. 35, 1433-1442.

Hägglund, M., Waldén, M., Ekstrand, J., (2008). Injuries among male and female elite football players. Scand.J.Med.Sci.Sports.

Hägglund, M., Waldén, M., Ekstrand, J., (2009). UEFA injury study--an injury audit of European Championships 2006 to 2008. Br.J.Sports Med. 43, 483-489.

Handoll, H. H., Rowe, B. H., Quinn, K. M., de, B. R., (2001). Interventions for preventing ankle ligament injuries. Cochrane.Database.Syst.Rev CD000018.

Hart, L., (2005). Effect of stretching on sport injury risk: a review. Clin.J.Sport Med. 15, 113.

Hartig, D. E., Henderson, J. M., (1999). Increasing hamstring flexibility decreases lower extremity overuse injuries in military basic trainees. Am.J.Sports Med. 27, 173-176.

Hass, C. J., Schick, E. A., Tillman, M. D., Chow, J. W., Brunt, D., Cauraugh, J. H., (2005). Knee biomechanics during landings: comparison of pre- and postpubescent females. Med.Sci.Sports Exerc. 37, 100-107.

Hawkins, R. D., Fuller, C. W., (1998). A preliminary assessment of professional footballers' awareness of injury prevention strategies. Br.J.Sports Med. 32, 140-143.

Hawkins, R. D., Fuller, C. W., (1999). A prospective epidemiological study of injuries in four English professional football clubs. Br.J.Sports Med. 33, 196-203.

Hawkins, R. D., Hulse, M. A., Wilkinson, C., Hodson, A., Gibson, M., (2001). The association football medical research programme: an audit of injuries in professional football. Br.J.Sports Med. 35, 43-47.

Heidt, R. S., Jr., Sweeterman, L. M., Carlonas, R. L., Traub, J. A., Tekulve, F. X., (2000). Avoidance of soccer injuries with preseason conditioning. Am.J.Sports Med. 28, 659-662.

Heiser, T. M., Weber, J., Sullivan, G., Clare, P., Jacobs, R. R., (1984). Prophylaxis and management of hamstring muscle injuries in intercollegiate football players. Am.J.Sports Med. 12, 368-370.

Herbert, R. D., Gabriel, M., (2002). Effects of stretching before and after exercising on muscle soreness and risk of injury: systematic review. BMJ 325, 468.

Hewett, T. E., Lindenfeld, T. N., Riccobene, J. V., Noyes, F. R., (1999). The effect of neuromuscular training on the incidence of knee injury in female athletes. A prospective study. Am.J.Sports Med. 27, 699-706.

Hewett, T. E., Myer, G. D., Ford, K. R., Heidt, R. S., Jr., Colosimo, A. J., McLean, S. G., van den Bogert, A. J., Paterno, M. V., Succop, P., (2005). Biomechanical measures of neuromuscular control and valgus loading of the knee predict anterior cruciate ligament injury risk in female athletes: a prospective study. Am.J.Sports Med. 33, 492-501.

Holme, E., Magnusson, S. P., Becher, K., Bieler, T., Aagaard, P., Kjaer, M., (1999). The effect of supervised rehabilitation on strength, postural sway, position sense and re-injury risk after acute ankle ligament sprain. Scand.J.Med.Sci.Sports 9, 104-109.

Hölmich, P., Larsen, K., Krogsgaard, K., Gluud, C., (2009). Exercise program for prevention of groin pain in football players: a cluster-randomized trial. Scand.J.Med.Sci.Sports.

Hölmich, P., Uhrskou, P., Ulnits, L., Kanstrup, I. L., Nielsen, M. B., Bjerg, A. M., Krogsgaard, K., (1999). Effectiveness of active physical training as treatment for long-standing adductor-related groin pain in athletes: randomised trial. Lancet 353, 439-443.

Hrysomallis, C., McLaughlin, P., Goodman, C., (2005). Does a balance deficit persist in Australian Football players with previous lower limb ligament injury? J Sci Med Sport 8, 85-91.

Hrysomallis, C., McLaughlin, P., Goodman, C., (2007). Balance and injury in elite Australian footballers. Int.J Sports Med 28, 844-847.

Hubscher, M., Zech, A., Pfeifer, K., Hansel, F., Vogt, L., Banzer, W., (2010). Neuromuscular training for sports injury prevention: a systematic review. Med.Sci.Sports Exerc. 42, 413-421.

Hupperets, M. D., Verhagen, E. A., van, M. W., (2008). The 2BFit study: is an unsupervised proprioceptive balance board training programme, given in addition to usual care, effective in preventing ankle sprain recurrences? Design of a randomized controlled trial. BMC.Musculoskelet.Disord. 9, 71.

Hupperets, M. D., Verhagen, E. A., van, M. W., (2009). Effect of unsupervised home based proprioceptive training on recurrences of ankle sprain: randomised controlled trial. BMJ 339, b2684.

Inklaar, H., (1994a). Soccer injuries. I: Incidence and severity. Sports Med. 18, 55-73.

Inklaar, H., (1994b). Soccer injuries. II: Aetiology and prevention. Sports Med. 18, 81-93.

Inklaar, H., Bol, E., Schmikli, S. L., Mosterd, W. L., (1996). Injuries in male soccer players: team risk analysis. Int.J.Sports Med. 17, 229-234.

Jarvinen, T. A., Kaariainen, M., Jarvinen, M., Kalimo, H., (2000). Muscle strain injuries. Curr.Opin.Rheumatol. 12, 155-161.

Johnson RJ, (2001). The ACL injury in female skiers. Prevention of non-contact ACL injuries. American Academy of Orthopaedic Surgeons, Rosemont, pp. 230-257.

Junge, A., Dvorak, J., Rösch, D., Graf-Baumann, T., Chomiak, J., Peterson, L., (2000). Psychological and Sport-Specific Characteristics of Football Players. Am.J Sports Med 28, 22-28.

Junge, A., Dvorak, J., (2000). Influence of definition and data collection on the incidence of injuries in football. Am.J.Sports Med. 28, S40-S46.

Junge, A., Dvorak, J., (2004). Soccer injuries: a review on incidence and prevention. Sports Med 34, 929-938.

Junge, A., Dvorak, J., Graf-Baumann, T., (2004a). Football injuries during the World Cup 2002. Am.J.Sports Med. 32, 23S-27S.

Junge, A., Dvorak, J., Graf-Baumann, T., Peterson, L., (2004b). Football injuries during FIFA tournaments and the Olympic Games, 1998-2001: development and implementation of an injury-reporting system. Am.J.Sports Med. 32, 80S-89S.

Junge, A., Rosch, D., Peterson, L., Graf-Baumann, T., Dvorak, J., (2002). Prevention of soccer injuries: a prospective intervention study in youth amateur players. Am.J.Sports Med. 30, 652-659.

Kofotolis, N. D., Kellis, E., Vlachopoulos, S. P., (2007). Ankle sprain injuries and risk factors in amateur soccer players during a 2-year period. Am.J Sports Med 35, 458-466.

Kujala, U. M., Orava, S., Jarvinen, M., (1997). Hamstring injuries. Current trends in treatment and prevention. Sports Med. 23, 397-404.

Lee, A. J., Lin, W. H., (2008). Twelve-week biomechanical ankle platform system training on postural stability and ankle proprioception in subjects with unilateral functional ankle instability. Clin.Biomech.(Bristol., Avon.) 23, 1065-1072.

Leetun, D. T., Ireland, M. L., Willson, J. D., Ballantyne, B. T., Davis, I. M., (2004). Core stability measures as risk factors for lower extremity injury in athletes. Med.Sci.Sports Exerc. 36, 926-934.

Lindenfeld, T. N., Schmitt, D. J., Hendy, M. P., Mangine, R. E., Noyes, F. R., (1994). Incidence of injury in indoor soccer. Am.J Sports Med 22, 364-371.

Ljungqvist, A., Jenoure, P. J., Engebretsen, L., Alonso, J. M., Bahr, R., Clough, A. F., de, B. G., Dvorak, J., Maloley, R., Matheson, G., Meeuwisse, W., Meijboom, E. J., Mountjoy, M., Pelliccia, A., Schwellnus, M., Sprumont, D., Schamasch, P., Gauthier, J. B., Dubi, C., (2009). The International Olympic Committee (IOC) consensus statement on periodic health evaluation of elite athletes, March 2009. Clin.J.Sport Med. 19, 347-365.

Lovell, R. J., Kirke, I., Siegler, J., McNaughton, L. R., Greig, M. P., (2007). Soccer half-time strategy influences thermoregulation and endurance performance. J.Sports Med.Phys Fitness 47, 263-269.

Luthje, P., Nurmi, I., Kataja, M., Belt, E., Helenius, P., Kaukonen, J. P., Kiviluoto, H., Kokko, E., Lehtipuu, T. P., Lehtonen, A., Liukkonen, T., Myllyniemi, J., Rasilainen, P., Tolvanen, E., Virtanen, H., Wallden, M., (1996). Epidemiology and traumatology of injuries in elite soccer: a prospective study in Finland. Scand.J.Med.Sci.Sports 6, 180-185.

LYN, (2010). FK LYNs offisielle hjemmeside - Oppstarten. http://www.lyn.no/index.aspx?id=28519, http://www.lyn.no/index.aspx?id=28519.

Lysens, R. J., Ostyn, M. S., Vanden, A. Y., Lefevre, J., Vuylsteke, M., Renson, L., (1989). The accident-prone and overuse-prone profiles of the young athlete. Am.J Sports Med 17, 612-619.

MacKay, J. M., Vincenten, J., (2009). Why isn't more injury prevention evidence-based? Int.J.Inj.Contr.Saf Promot. 16, 89-96.

Maffey, L., Emery, C., (2007). What are the risk factors for groin strain injury in sport? A systematic review of the literature. Sports Med. 37, 881-894.

Mahler, P. B., Donaldson, A., (2010). The limits of prevention - sports injuries as an example. Int.J.Inj.Contr.Saf Promot. 17, 69-72.

Mandelbaum, B. R., Silvers, H. J., Watanabe, D. S., Knarr, J. F., Thomas, S. D., Griffin, L. Y., Kirkendall, D. T., Garrett, W., Jr., (2005). Effectiveness of a neuromuscular and proprioceptive training program in preventing anterior cruciate ligament injuries in female athletes: 2-year follow-up. Am.J.Sports Med. 33, 1003-1010.

McGuine, T. A., Greene, J. J., Best, T., Leverson, G., (2000). Balance as a predictor of ankle injuries in high school basketball players. Clin J Sport Med 10, 239-244.

McGuine, T. A., Keene, J. S., (2006). The effect of a balance training program on the risk of ankle sprains in high school athletes. Am.J Sports Med 34, 1103-1111.

McHugh, M. P., Tyler, T. F., Mirabella, M. R., Mullaney, M. J., Nicholas, S. J., (2007). The effectiveness of a balance training intervention in reducing the incidence of noncontact ankle sprains in high school football players. Am.J Sports Med 35, 1289-1294.

McHugh, M. P., Tyler, T. F., Tetro, D. T., Mullaney, M. J., Nicholas, S. J., (2006). Risk factors for noncontact ankle sprains in high school athletes: the role of hip strength and balance ability. Am.J Sports Med 34, 464-470.

McKay, G. D., Goldie, P. A., Payne, W. R., Oakes, B. W., (2001). Ankle injuries in basketball: injury rate and risk factors. Br.J Sports Med 35, 103-108.

McKeon, P. O., Hertel, J., (2008). Systematic review of postural control and lateral ankle instability, part I: can deficits be detected with instrumented testing. J Athl.Train. 43, 293-304.

McKeon, P. O., Mattacola, C. G., (2008). Interventions for the prevention of first time and recurrent ankle sprains. Clin Sports Med 27, 371-82, viii.

McLean, S. G., Fellin, R. E., Suedekum, N., Calabrese, G., Passerallo, A., Joy, S., (2007). Impact of fatigue on gender-based high-risk landing strategies. Med.Sci.Sports Exerc. 39, 502-514.

van Mechelen, W., (1997). Sports injury surveillance systems. 'One size fits all'? Sports Med. 24, 164-168.

van Mechelen, W., Hlobil, H., Kemper, H. C., (1992). Incidence, severity, aetiology and prevention of sports injuries. A review of concepts. Sports Med. 14, 82-99.

Meeuwisse WH, (1994). Assessing causation in sport injury: A multifactorial model. pp. 166-170.

Meeuwisse, W. H., (1991). Predictability of sports injuries. What is the epidemiological evidence? Sports Med. 12, 8-15.

Meeuwisse, W. H., Sellmer, R., Hagel, B. E., (2003). Rates and risks of injury during intercollegiate basketball. Am.J.Sports Med. 31, 379-385.

Melnyk, M., Schloz, C., Schmitt, S., Gollhofer, A., (2009). Neuromuscular ankle joint stabilisation after 4-weeks WBV training. Int.J.Sports Med. 30, 461-466.

Mjølsnes, R., Árnason, A., Osthagen, T., Raastad, T., Bahr, R., (2004). A 10-week randomized trial comparing eccentric vs. concentric hamstring strength training in well-trained soccer players. Scand.J.Med.Sci.Sports 14, 311-317.

Mohammadi, F., (2007). Comparison of 3 preventive methods to reduce the recurrence of ankle inversion sprains in male soccer players. Am.J.Sports Med. 35, 922-926.

Morelli, V., Weaver, V., (2005). Groin injuries and groin pain in athletes: part 1. Prim.Care 32, 163-183.

Morgan, B. E., Oberlander, M. A., (2001). An examination of injuries in major league soccer. The inaugural season. Am.J.Sports Med. 29, 426-430.

Myer, G. D., Ford, K. R., Paterno, M. V., Nick, T. G., Hewett, T. E., (2008). The effects of generalized joint laxity on risk of anterior cruciate ligament injury in young female athletes. Am.J.Sports Med. 36, 1073-1080.

Myklebust, G., Engebretsen, L., Braekken, I. H., Skjolberg, A., Olsen, O. E., Bahr, R., (2003). Prevention of anterior cruciate ligament injuries in female team handball players: a prospective intervention study over three seasons. Clin.J.Sport Med. 13, 71-78.

NFF, (2009). NFF i tall - Her finner du nøkkeltall om norsk fotball. NFF http://www.fotball.no/toppmeny/Om-NFF/NFF-i-tall/ 30.juni 2009.

Nielsen, A. B., Yde, J., (1989). Epidemiology and traumatology of injuries in soccer. Am.J Sports Med 17, 803-807.

Noonan, T. J., Garrett, W. E., Jr., (1992). Injuries at the myotendinous junction. Clin.Sports Med. 11, 783-806.

Olsen, O. E., Myklebust, G., Engebretsen, L., Holme, I., Bahr, R., (2005). Exercises to prevent lower limb injuries in youth sports: cluster randomised controlled trial. BMJ 330, 449.

Orchard, J., Marsden, J., Lord, S., Garlick, D., (1997). Preseason hamstring muscle weakness associated with hamstring muscle injury in Australian footballers. Am.J.Sports Med. 25, 81-85.

Orchard, J., Seward, H., (2002). Epidemiology of injuries in the Australian Football League, seasons 1997-2000. Br.J.Sports Med. 36, 39-44.

Orchard, J., Wood, T., Seward, H., Broad, A., (1998). Comparison of injuries in elite senior and junior Australian football. J.Sci.Med.Sport 1, 83-88.

Orchard, J. W., (2001). Intrinsic and extrinsic risk factors for muscle strains in Australian football. Am.J.Sports Med. 29, 300-303.

Östenberg, A., Roos, H., (2000). Injury risk factors in female European football. A prospective study of 123 players during one season. Scand J Med Sci Sports 10, 279-285.

Petersen, J., Hölmich, P., (2005). Evidence based prevention of hamstring injuries in sport. Br.J.Sports Med. 39, 319-323.

Petersen, J., Thorborg, K., Nielsen, M. B., Hölmich, P., (2009). Acute hamstring injuries in Danish elite football: A 12-month prospective registration study among 374 players. Scand.J.Med.Sci.Sports.

Peterson, L., Junge, A., Chomiak, J., Graf-Baumann, T., Dvorak, J., (2000). Incidence of football injuries and complaints in different age groups and skill-level groups. Am.J Sports Med 28, S51-S57.

Quinn, K., Parker, P., de, B. R., Rowe, B., Handoll, H., (2000). Interventions for preventing ankle ligament injuries. Cochrane.Database.Syst.Rev CD000018.

Reilly, T., Bangsbo, J., Franks, A., (2000). Anthropometric and physiological predispositions for elite soccer. J.Sports Sci. 18, 669-683.

Roberts, W. O., Brust, J. D., Leonard, B., Hebert, B. J., (1996). Fair-play rules and injury reduction in ice hockey. Arch.Pediatr.Adolesc.Med. 150, 140-145.

Roos, E. M., Brandsson, S., Karlsson, J., (2001). Validation of the foot and ankle outcome score for ankle ligament reconstruction. Foot Ankle Int. 22, 788-794.

Roos, E. M., Roos, H. P., Lohmander, L. S., Ekdahl, C., Beynnon, B. D., (1998). Knee Injury and Osteoarthritis Outcome Score (KOOS)--development of a self-administered outcome measure. J.Orthop.Sports Phys.Ther. 28, 88-96.

Söderman, K., Werner, S., Pietila, T., Engström, B., Alfredson, H., (2000). Balance board training: prevention of traumatic injuries of the lower extremities in female soccer players? A prospective randomized intervention study. Knee.Surg.Sports Traumatol.Arthrosc. 8, 356-363.

Soligard, T., Myklebust, G., Steffen, K., Holme, I., Silvers, H., Bizzini, M., Junge, A., Dvorak, J., Bahr, R., Andersen, T. E., (2008). Comprehensive warm-up programme to prevent injuries in young female footballers: cluster randomised controlled trial. BMJ 337, a2469.

Stasinopoulos, D., (2004). Comparison of three preventive methods in order to reduce the incidence of ankle inversion sprains among female volleyball players. Br.J.Sports Med. 38, 182-185.

Steffen, K., Myklebust, G., Andersen, T. E., Holme, I., Bahr, R., (2008a). Self-reported injury history and lower limb function as risk factors for injuries in female youth soccer. Am.J.Sports Med. 36, 700-708.

Steffen, K., Myklebust, G., Olsen, O. E., Holme, I., Bahr, R., (2008b). Preventing injuries in female youth football--a cluster-randomized controlled trial. Scand.J.Med.Sci.Sports 18, 605-614.

Steffen, K., Pensgaard, A. M., Bahr, R., (2008c). Self-reported psychological characteristics as risk factors for injuries in female youth football. Scand.J.Med.Sci.Sports.

Stølen, T., Chamari, K., Castagna, C., Wisløff, U., (2005). Physiology of soccer: an update. Sports Med. 35, 501-536.

Surve, I., Schwellnus, M. P., Noakes, T., Lombard, C., (1994). A fivefold reduction in the incidence of recurrent ankle sprains in soccer players using the Sport-Stirrup orthosis. Am.J Sports Med 22, 601-606.

Taerk, G. S., (1977). The injury-prone athlete: a psychosocial approach. J Sports Med Phys.Fitness 17, 186-194.

Taimela, S., Kujala, U. M., Osterman, K., (1990). Intrinsic risk factors and athletic injuries. Sports Med 9, 205-215.

Taunton, J. E., Ryan, M. B., Clement, D. B., McKenzie, D. C., Lloyd-Smith, D. R., Zumbo, B. D., (2003). A prospective study of running injuries: the Vancouver Sun Run "In Training" clinics. Br.J.Sports Med. 37, 239-244.

Thacker, S. B., Gilchrist, J., Stroup, D. F., Kimsey, C. D., Jr., (2004). The impact of stretching on sports injury risk: a systematic review of the literature. Med.Sci.Sports Exerc. 36, 371-378.

Thacker, S. B., Stroup, D. F., Branche, C. M., Gilchrist, J., Goodman, R. A., Porter, K. E., (2003). Prevention of knee injuries in sports. A systematic review of the literature. J.Sports Med.Phys Fitness 43, 165-179.

Thacker, S. B., Stroup, D. F., Branche, C. M., Gilchrist, J., Goodman, R. A., Weitman, E. A., (1999). The prevention of ankle sprains in sports. A systematic review of the literature. Am.J.Sports Med. 27, 753-760.

Trojian, T. H., McKeag, D. B., (2006). Single leg balance test to identify risk of ankle sprains. Br.J Sports Med 40, 610-613.

Tropp, H., Askling, C., Gillquist, J., (1985). Prevention of ankle sprains. Am.J.Sports Med. 13, 259-262.

Tumilty, D., (1993). Physiological characteristics of elite soccer players. Sports Med. 16, 80-96.

Turl, S. E., George, K. P., (1998). Adverse neural tension: a factor in repetitive hamstring strain? J.Orthop.Sports Phys Ther 27, 16-21.

Twomey, D., Finch, C., Roediger, E., Lloyd, D. G., (2009). Preventing lower limb injuries: is the latest evidence being translated into the football field? J.Sci.Med.Sport 12, 452-456.

Tyler, T. F., McHugh, M. P., Mirabella, M. R., Mullaney, M. J., Nicholas, S. J., (2006). Risk factors for noncontact ankle sprains in high school football players: the role of previous ankle sprains and body mass index. Am.J Sports Med 34, 471-475.

Tyler, T. F., Nicholas, S. J., Campbell, R. J., Donellan, S., McHugh, M. P., (2002). The effectiveness of a preseason exercise program to prevent adductor muscle strains in professional ice hockey players. Am.J.Sports Med. 30, 680-683.

Tyler, T. F., Nicholas, S. J., Campbell, R. J., McHugh, M. P., (2001). The association of hip strength and flexibility with the incidence of adductor muscle strains in professional ice hockey players. Am.J.Sports Med. 29, 124-128.

Upton, P. A., Noakes, T. D., Juritz, J. M., (1996). Thermal pants may reduce the risk of recurrent hamstring injuries in rugby players. Br.J.Sports Med. 30, 57-60.

Verhagen, E., van der, B. A., Twisk, J., Bouter, L., Bahr, R., van, M. W., (2004). The effect of a proprioceptive balance board training program for the prevention of ankle sprains: a prospective controlled trial. Am.J.Sports Med. 32, 1385-1393.

Verhagen, E. A., van, M. W., de, V. W., (2000). The effect of preventive measures on the incidence of ankle sprains. Clin.J.Sport Med. 10, 291-296.

Verrall, G. M., Slavotinek, J. P., Barnes, P. G., Fon, G. T., Spriggins, A. J., (2001). Clinical risk factors for hamstring muscle strain injury: a prospective study with correlation of injury by magnetic resonance imaging. Br.J Sports Med 35, 435-439.

Waldén, M., Hägglund, M., Ekstrand, J., (2005a). Injuries in Swedish elite football--a prospective study on injury definitions, risk for injury and injury pattern during 2001. Scand J Med Sci Sports 15, 118-125.

Waldén, M., Hägglund, M., Ekstrand, J., (2005b). UEFA Champions League study: a prospective study of injuries in professional football during the 2001-2002 season. Br.J.Sports Med. 39, 542-546.

Waldén, M., Hägglund, M., Ekstrand, J., (2006). High risk of new knee injury in elite footballers with previous anterior cruciate ligament injury. Br.J.Sports Med. 40, 158-162.

Waldén, M., Hägglund, M., Ekstrand, J., (2007). Football injuries during European Championships 2004-2005. Knee.Surg.Sports Traumatol.Arthrosc. 15, 1155-1162.

Wang, H. K., Chen, C. H., Shiang, T. Y., Jan, M. H., Lin, K. H., (2006). Risk-factor analysis of high school basketball-player ankle injuries: a prospective controlled cohort study evaluating postural sway, ankle strength, and flexibility. Arch.Phys.Med Rehabil. 87, 821-825.

Werner, J., Hägglund, M., Waldén, M., Ekstrand, J., (2009). UEFA injury study: a prospective study of hip and groin injuries in professional football over seven consecutive seasons. Br.J.Sports Med. 43, 1036-1040.

Wester, J. U., Jespersen, S. M., Nielsen, K. D., Neumann, L., (1996). Wobble board training after partial sprains of the lateral ligaments of the ankle: a prospective randomized study. J.Orthop.Sports Phys Ther 23, 332-336.

Willems, T. M., Witvrouw, E., Delbaere, K., Mahieu, N., De, B., I, De, C. D., (2005). Intrinsic risk factors for inversion ankle sprains in male subjects: a prospective study. Am.J Sports Med 33, 415-423.

Wisløff, U., Helgerud, J., Hoff, J., (1998). Strength and endurance of elite soccer players. Med Sci Sports Exerc. 30, 462-467.

Witvrouw, E., Danneels, L., Asselman, P., D'Have, T., Cambier, D., (2003). Muscle flexibility as a risk factor for developing muscle injuries in male professional soccer players. A prospective study. Am.J.Sports Med. 31, 41-46.

Wong, P., Hong, Y., (2005). Soccer injury in the lower extremities. Br.J.Sports Med. 39, 473-482.

Woods, C., Hawkins, R., Hulse, M., Hodson, A., (2002). The Football Association Medical Research Programme: an audit of injuries in professional football-analysis of preseason injuries. Br.J Sports Med 36, 436-441.

Woods, C., Hawkins, R., Hulse, M., Hodson, A., (2003). The Football Association Medical Research Programme: an audit of injuries in professional football: an analysis of ankle sprains. Br.J Sports Med 37, 233-238.

Woods, C., Hawkins, R. D., Maltby, S., Hulse, M., Thomas, A., Hodson, A., (2004). The Football Association Medical Research Programme: an audit of injuries in professional football--analysis of hamstring injuries. Br.J Sports Med 38, 36-41.

Worrell, T. W., (1994). Factors associated with hamstring injuries. An approach to treatment and preventative measures. Sports Med. 17, 338-345.

Yung, P. S., Chan, R. H., Wong, F. C., Cheuk, P. W., Fong, D. T., (2007). Epidemiology of injuries in Hong Kong elite badminton athletes. Res.Sports Med. 15, 133-146.

Zazulak, B. T., Hewett, T. E., Reeves, N. P., Goldberg, B., Cholewicki, J., (2007). Deficits in neuromuscular control of the trunk predict knee injury risk: a prospective biomechanical-epidemiologic study. Am.J.Sports Med. 35, 1123-1130.

Papers I-V

Paper I

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Prevention of Injuries Among Male Soccer Players

A Prospective, Randomized Intervention Study Targeting Players With Previous Injuries or Reduced Function

Anders H. Engebretsen,[*†] Grethe Myklebust,[†] PT, PhD, Ingar Holme,[†] PhD,
Lars Engebretsen,[†‡] MD PhD, and Roald Bahr,[†] MD, PhD
From [†]Oslo Sports Trauma Research Center, Norwegian School of Sports Sciences, Oslo Norway, and the [‡]Department of Orthopaedic Surgery, Ulleval University Hospital, University of Oslo, Oslo, Norway

Background: This study was conducted to investigate whether the most common injuries in soccer could be prevented, and to determine if a simple questionnaire could identify players at increased risk.

Hypothesis: Introduction of targeted exercise programs to male soccer players with a history of previous injury or reduced function in the ankle, knee, hamstring, or groin will prevent injuries.

Study Design: Randomized controlled trial; Level of evidence, 2.

Methods: A total of 508 players representing 31 teams were included in the study. A questionnaire indicating previous injury and/or reduced function as inclusion criteria was used to divide the players into high-risk (HR) (76%) and low-risk (LR) groups. The HR players were randomized individually into an HR intervention group or HR control group.

Results: A total of 505 injuries were reported, sustained by 56% of the players. The total injury incidence was a mean of 3.2 (95% confidence interval [CI], 2.5-3.9) in the LR control group, 5.3 (95% CI, 4.6-6.0) in the HR control group (P = .0001 vs the LR control group), and 4.9 (95% CI, 4.3-5.6) in the HR intervention group (P = .50 vs the HR control group). For the main outcome measure, the sum of injuries to the ankle, knee, hamstring, and groin, there was also a significantly lower injury risk in the LR control group compared with the 2 other groups, but no difference between the HR intervention group and the HR control group. Compliance with the training programs in the HR intervention group was poor, with only 27.5% in the ankle group, 29.2% in the knee group, 21.1% in the hamstring group, and 19.4% in the groin defined as having carried out the minimum recommended training volume.

Conclusion: The players with a significantly increased risk of injury were able to be identified through the use of a questionnaire, but player compliance with the training programs prescribed was low and any effect of the intervention on injury risk could not be detected.

Keywords: football; injury prevention; ankle injuries; knee injuries; hamstring injuries; groin injuries; risk factors; randomized controlled trial

Although differences in study design and injury definitions make a direct comparison between studies difficult,[13] the incidence of injuries among adult male soccer players on the elite level has been estimated to range between 25 and 35 per 1000 game-hours.[5,14,19,34] Thus, the injury risk is considerable and high compared with most other team sports.[19] Studies from the professional leagues in Europe (Norway, Sweden, Iceland, Britain, Fédération Internationale de Football Association [FIFA], and Union of European Football Associations [UEFA]) agree that injuries to the lower extremities constitute the biggest problem.[3,5,14,18,19,33,34] The 4 dominating injury types in soccer are sprains to the ankle and knee and strains to the hamstring and groin. These account for more than 50% of all injuries, and prevention programs for soccer should therefore target these.

*Address correspondence to Anders H. Engebretsen, Oslo Sports Trauma Research Center, Norwegian School of Sports Science, PO Box 4014 Ullevål Stadion, N-0806 Oslo, Norway (e-mail: Anders.Engebretsen@nih.no).

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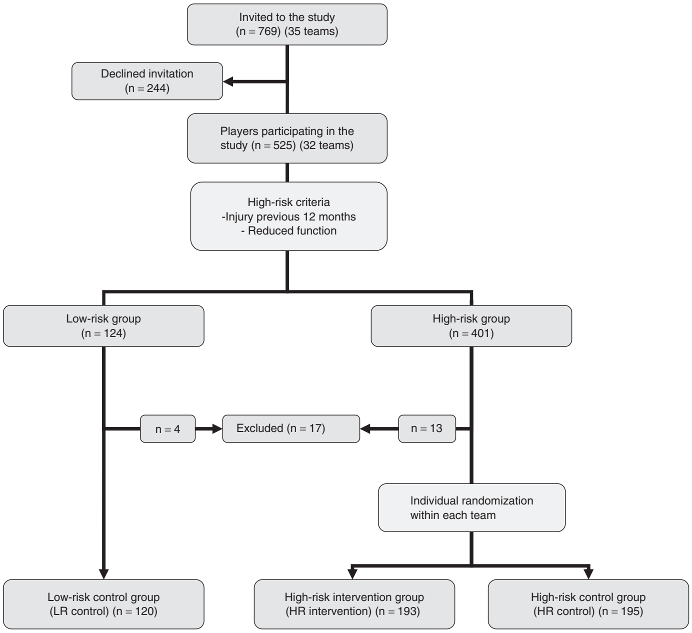

Figure 1. Flow chart showing movement of patients through the study.

As early as 1983, Ekstrand et al[10] showed a significant reduction in the overall number of soccer injuries through a 7-part prevention program. The rate of the most common types of soccer injuries, sprains and strains to ankles and knees, was reduced significantly. However, in more than 20 years, only 9 more injury prevention studies have been published in soccer, and only 5 of them among men at the senior level.[4,7,8,31,32] Tropp et al[32] showed that a balance training program or the use of orthoses resulted in significantly fewer ankle sprains than for a control group. Later, orthoses and proprioceptive training were proven useful to prevent ankle and knee injuries, respectively.[8,31] Finally, Askling et al[7] and Arnason et al[4] have recently observed a reduction in hamstring strains among male players through eccentric strength-training programs.

Although the incidence and pattern (injury type, localization, and severity) of injuries in soccer have been described in detail,[9,12,24,29] much less is known about their risk factors. Therefore, we do not know which players should be targeted, for instance through specific training programs. The risk of injury seems to be influenced by age,[11,17,24,29] sex,[17,25] and level of play.[12,24] In addition, a history of previous injury was shown to be a significant risk factor for ankle sprains in soccer as early as 1985.[32] This was recently confirmed by Arnason et al[6] in the largest cohort study from elite soccer to date, in which the main risk factors for the 4 main injury types were previous injury and age. We therefore hypothesized that players with a history of previous injury or symptoms indicating reduced function would represent a group with an increased injury risk, who should be targeted with specific prevention programs addressing their reported deficits. A previous injury could compromise joint function through reduced mechanical instability or neuromuscular control, or muscle function through scar tissue formation, reduced strength, or more subtle changes in the length-tension relationship.

One aim of this study was therefore to examine whether we could identify players with an increased risk of injury using a questionnaire focusing on history of previous injury and joint/muscle function. We also wanted to examine if exercise programs targeting players with an increased risk of injury could prevent the 4 most common injury types in soccer, ankle and knee sprains and hamstring and groin strains.

METHODS

Teams playing in the Norwegian 1st, 2nd, or the top of the 3rd division that were geographically located in the proximity of Oslo (n = 35 teams, 769 players) were invited to participate in the study. The 8 3rd division teams included either won their league or finished as first runners-up the previous season, resulting in a relatively homogeneous group of teams, even if they competed in 3 different divisions.

Three of the teams (n = 60 players) declined the invitation to participate, 177 players did not show up for testing, 3 players did not speak Norwegian and could therefore not complete the questionnaire, and 4 players were excluded for other reasons (Figure 1). Hence, 244 of the players invited could not be included. In addition, 1 team (n = 17 players) was later excluded because the physiotherapist did not instruct the intervention group players nor record

Figure 2. Example of an ankle exercise. The exercise was prescribed to be performed with a straight leg and with a gradual progression in difficulty (see Table 1).

Figure 3. Example of a knee exercise. The exercise was prescribed to be performed in the knee-over-toe position and a flexed knee, with gradual progression in difficulty (see Table 2).

injuries, resulting in a final sample of 508 players representing 31 teams.

The teams were tested during the preseason (January through March 2004) at the Norwegian School of Sports Sciences. The players were asked to fill out a questionnaire in 5 parts. The first section consisted of general information (date of birth, team, field position, and player experience). The second through fifth sections included information on the ankle, knee, hamstring, and groin, respectively. Each of these sections covered the history of previous injuries (severity, nature, and number of months since the most recent injury, use of protective gear such as tape or brace, and if the injury had caused the player to miss matches), and a function score for each region. The questionnaires used to assess function were the Foot and Ankle Outcome Score (FAOS) and Knee Osteoarthritis Outcome Score (KOOS) score, which were translated to Norwegian.[27,28] For the hamstring and groin, we developed similar function scores, Hamstring Outcome Score (HaOS) and Groin Outcome Score (GrOS), based on the same principles as FAOS and KOOS, only specific to these regions and their typical symptoms (see Appendix, available in the online version of this article at http://ajsm.sagepub.com/cgi/ content/full/X/X/X/DC1/).

Based on the questionnaire, the 508 players were divided into 2 groups (Figure 1), a high-risk (HR) and a low-risk (LR) group. The criteria for classifying a player as having an assumed increased risk of injury were a history of an acute injury to the ankle, knee, hamstring or groin during the previous 12 months or a reduced function with

Figure 4. Groin exercise. A variety of different exercises were prescribed for strengthening of the groin muscles. In this example, the player is pushing the legs together for 15 seconds while keeping a ball between the knees (see Table 3).

an average score of less than 80% for any of the body parts mentioned. A player fulfilling any of the inclusion criteria for any of the 4 body parts was assigned to the HR group. The players in the HR group were randomized individually, but stratified within each team, into 2 groups, the HR intervention group and the HR control group (Figure 1). In this way, each team would normally have players from all 3 groups (HR intervention, HR control, and LR control).

The players in the HR intervention group were only included on the basis of the inclusion criteria they fulfilled, meaning that they only received a training program for the body part(s) to which they were assumed to have an increased risk of injury. In a situation in which a player

TABLE 1
The Ankle Exercise Program[32,a]

Weeks 1-2	
Balance board	Both legs on the board, with arms crossed. Attempt to stand still and maintain the balance.
	Similar exercise, but now performed on 1 leg.
	Both legs on the board, bouncing a ball alternately with both hands, standing as still as possible during the exercise.
	Both legs on the board, throwing the ball and catching it.
Balance pad	One leg on the pad, maintaining balance for 30 seconds on alternating legs.
	Jumping exercise—from outside the pad, landing on alternating legs.
Weeks 3-5	
Balance board	Ball juggling performed while standing on 1 leg.
Balance pad	Bouncing the ball around the pad while standing on 1 leg.
	Calf raise while standing on both legs on the pad.
Weeks 6-10	
Balance board	Soccer-specific exercises, juggling the ball while standing on 1 leg, also combining both the balance board and balance pad, placing the pad on top of the board.
Balance pad	Closing the eyes while standing on 1 leg, and other exercises including landing on 1 or 2 legs while jumping from a box/stairs.

[a]All exercises were prescribed to be performed with a straight leg (no knee flexion) (Figure 2) and with a gradual progression in difficulty. The players were instructed to switch between the balance board and pad, and, as they became more proficient, to include ball-based exercises while keeping their balance.

TABLE 2
The Knee Exercise Program[8,23,a]

Weeks 1-2	
Balance board	Both legs on the board, with arms crossed, always keeping the knee-over-toe position.
	Similar exercise, but now performed on 1 leg.
	Both legs on the board, bouncing a ball alternately with both hands, standing as still as possible during the exercise.
	Both legs on the board, throwing the ball and catching it.
Balance pad	One leg on the pad, maintaining balance for 30 seconds on alternating legs.
	Walk onto the pad, stopping and keeping the balance.
	Jumping exercise—from outside the pad, landing on alternating legs.
Weeks 3-5	
Balance board	Ball juggling performed while standing on 1 leg.
	Two-legged squats, with knee-over-toe position.
Balance pad	Bouncing the ball around the pad while standing on 1 leg.
Weeks 6-10	
Balance board	Soccer-specific exercises, juggling the ball while standing on 1 leg, also combining both the balance board and balance pad, placing the pad on top of the board.
Balance pad	Closing the eyes while standing on 1 leg, and other exercises including landing on 1 or 2 legs while jumping from a box/stairs.
	One-legged squats, and balance exercises while closing the eyes.
Floor exercise	One-legged jumping on 1 foot in an imaginary zig-zag course.

[a]All exercises were prescribed to be performed with the knee-over-toe position and a flexed knee (Figure 3) with gradual progression in difficulty. As with the ankle program, the players were instructed to switch between the balance board and pad, and include ball-based exercises as they progressed.

ended up with 4 programs, the team physical therapist was asked to merge the programs into 1 continuous program. However, even if a player fulfilled the inclusion criteria for 1 body part on only 1 side, he was asked to perform the prevention exercises for both legs.

The players were asked to complete the ankle, knee, and groin training programs (Tables 1 through 3, Figures 2 through 4) 3 times a week for 10 weeks during the preseason, in separate training sessions done in addition to the regular team training. For the hamstring program (Table 4, Figure 5), a 10-week progression was prescribed.[22] The intervention players were also asked to perform the exercises once per week for the rest of the season as maintenance. The programs were meant to progress in difficulty, to challenge the players as their performance improved. The players were also asked to report all exercises they performed on a form, checking a box if they had carried out the preventive training that day. The form covered all 10 weeks for compliance assessment.

Most of the teams from the 1st and 2nd divisions already had a physical therapist working with the team. When there was no physical therapist attached to the team, we provided them with one. Each physical therapist was rewarded with a stipend (10 000 NOK, or approximately 1900 USD). In addition to reporting injuries throughout the preseason and season, the physical therapist was

TABLE 3
The Groin Exercises[16,a]

Warm-up	Keeping a ball between the extended legs, pushing the legs together for 15 s, while lying on the ground. Repeated 10×. Similar exercise, only difference having the knees flexed and the ball between the knees.
Transverse abdominal muscles	Lie facing the ground, only resting on the forearms and toes in a straight position, contracting the abdominal muscles, "forcing the umbilicus inwards." Performed in 20 s, repeated 5×.
Sideways jumping	Knee-over-toe position while jumping sideways with arms resting on the hips.
Sliding	Wearing only socks, slide a leg alternately away and towards the other that is bearing the weight. The exercise can be performed both sideways and diagonally for 30-60 s before switching legs.
Diagonal walking	Exercise described by Holmich et al[16] performed 5 × 15 s on each leg.

[a]The players were instructed to perform the exercise 3 times a week for approximately 15 minutes. A ball was needed for some of the exercises (Figure 4), and the exercises could be performed without warming up.

TABLE 4
The Hamstring Exercise Program[a]

Week	No. of Training Sessions Per Week	No. of Repetitions
1	1	5 + 5
2	2	6 + 6
3	3	3 × 6-8
4	3	3 × 8-10
5-10	3	12 + 10 + 8

[a]The Nordic hamstring exercise is performed standing on the knees on a soft foundation, slowly lowering the body toward the ground using the hamstrings while the feet are held by a partner (Figure 5). Progression is achieved by increasing the initial speed, and eventually having a partner push forward.

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responsible for instructing all the players who were randomized into the HR intervention group in their training programs. Each player was given a folder describing the exercises he was asked to do, as well as any necessary equipment such as balance mats and balance boards.

An injury was defined as any physical complaint sustained by a player that resulted from a soccer match or soccer training, resulting in a player being unable to take a full part in future soccer training or match play ("time-loss" injury). Acute injuries were defined as injuries with a sudden onset associated with a known trauma, whereas overuse injuries were those with a gradual onset without any known trauma. Injuries were classified into 3 severity categories according to the time it took until the player was fully fit to take part in all types of organized soccer play: minor (1-7 days), moderate (8-28 days), and major (>28 days).

Match exposure was defined as play between teams from different clubs, while training exposure was defined as team-based and individual physical activities under the control or guidance of the team coaching or fitness staff aimed at maintaining or improving soccer skills or physical condition. All injuries were categorized by the authors based on the injury reports from each physiotherapist.

The main outcome measure was the sum of the risk for an ankle sprain, knee sprain, groin strain, or hamstring strain.

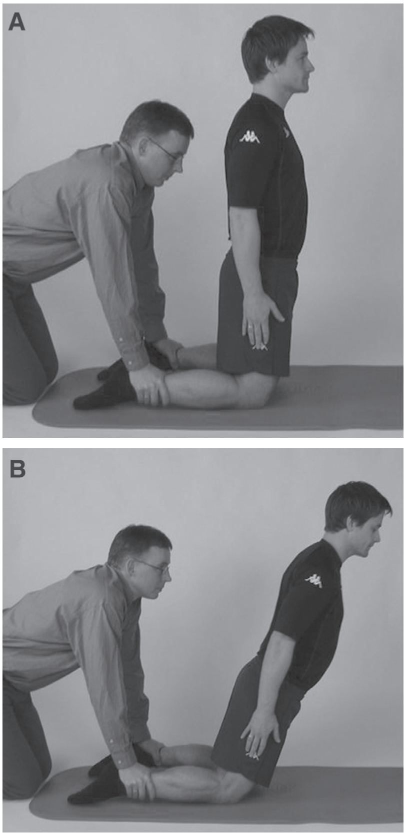

Figure 5. The hamstring exercise program. (A) start position. The player stands on his knees on a soft foundation with the feet being held by a partner. (B) slowly lowering the body toward the ground using the hamstrings while focusing on keeping the body straight (see Table 4).

Statistical Methods

Exposure was calculated in hours as the sum of all individual exposures recorded during training and match play

TABLE 5
Match, Training, and Total Exposure, Number of Injuries, and Injury Incidence (With 95% Confidence Intervals) for the 3 Groups Throughout the Season[a]

	Training			Match			Total		
	Exposure (h)	Injuries	Incidence (per 1000 h)	Exposure (h)	Injuries	Incidence (per 1000 h)	Exposure (hours)	Injuries	Incidence (per 1000 h)
HR intervention (n = 193)	34 422	100	2.9 (2.3-3.5)	7434	93	12.5 (10.0-15.1)	41 856	207	4.9 (4.3-5.6)
HR control (n = 195)	33 757	103	3.1 (2.5-3.6)	7156	100	14.0 (11.2-16.7)	40 913	216	5.3 (4.6-6.0)
LR control (n = 120)	20 925	40	1.9 (1.3-2.5)	4417	34	7.7 (5.1-10.3)	25 342	82	3.2 (2.5-3.9)
Total	89 103	243	2.7 (2.4-3.1)	19 008	227	11.9 (10.4-13.5)	108 111	505	4.7 (4.3-5.1)

[a]HR, high risk; LR, low risk.

during the season. The injury rate was compared between the HR control group and the HR intervention group, and the HR control group and the LR control group, respectively, using a *z* test, reporting 95% confidence intervals (CIs) based on the Poisson model. Chi-square tests were used to compare the proportion of injured players between the HR intervention group and the HR control group, and between the HR control group and the LR control group, respectively. Otherwise, results are presented as the means with standard deviations.

RESULTS

Screening and Randomization

Of the 508 players included in the study, 388 (76%) were assumed to have an increased risk for 1 or more injury types based on their history of previous injury and/or function scores. Of these, 195 players were randomized to the HR control group and 193 players to the HR intervention group (Figure 1). In the intervention group, 2 players were asked to perform all of the 4 training programs; 22 players, 3 programs; 62 players, 2 programs; and 107 players, 1 program. Of the 305 training programs prescribed, 102 were for the ankle, 65 for the knee, 76 for the hamstring, and 62 for the groin.

Player Exposure

The total exposure to match play and training was 108 111 player hours (Table 5), and there was no difference in mean player exposure between the HR intervention group (217 ± 94 hours), the HR control group (210 ± 103 hours), and the LR control group (211 ± 88 hours).

Injuries

A total of 505 injuries were reported (Table 5), sustained by 283 (56%) of the 508 players included in the study. In the LR control group, there were 82 injuries, while there were 216 injuries in the HR control group and 207 injuries in the HR intervention group. There was no difference in the incidence of injuries between the HR intervention group and the HR control group (relative risk [RR], 0.94; 95% CI, 0.77-1.13), while the incidence was lower in the LR control group than both other groups (RR, 0.65 vs the HR intervention group; 95% CI, 0.51-0.85; RR, 0.61 vs the HR control group; 95% CI, 0.48-0.79).

TABLE 6
Injury Type and Injury Severity (Based on Time Loss) in the 3 Groups[a]

	HR Intervention Group (n = 193)	HR Control Group (n = 195)	LR Control Group (n = 120)
Injury type			
Acute (%)	143 (41)	153 (43)	57 (16)
Overuse (%)	62 (42)	61 (41)	25 (17)
Other (%)	2 (50)	2 (50)	0 (0)
Time loss			
1-3 days (%)	37 (7)	54 (11)	24 (5)
4-7 days (%)	47 (9)	42 (8)	13 (3)
1-4 weeks (%)	81 (16)	66 (13)	27 (5)
>4 weeks (%)	30 (6)	40 (8)	12 (2)
Not specified (%)	12 (2)	14 (3)	6 (1)

[a]Percentages are shown within each group. HR, high risk; LR, low risk.

During the season, 45.8% of the players in the LR control group (55 of 120 players) sustained 1 or more injuries, compared with 58.5% in the HR control group (114 of 195 players; $P = .029$ vs the LR control group; χ^2 test) and 59.1% in the HR intervention group (114 of 193 players; $P = .90$ vs the HR control group).

There was no difference in injury severity among the 3 groups (Table 6).

Intervention Outcome: Intention-to-Treat Analysis

For the main outcome measure, the sum of injuries to the ankle, knee, hamstrings, and groin, the total incidence was 2.3 injuries per 1000 playing hours (95% CI, 2.1-2.6). The corresponding figures were 1.3 (95% CI, 0.9-1.8) for the LR control group, 2.8 (95% CI, 2.3-3.3) in the HR control group, and 2.6 (95% CI, 2.1-3.0) in the HR intervention group. There was a significantly lower injury risk in the LR

TABLE 7
Intention-to-Treat Analysis for Ankle, Knee, Hamstring, and Groin Injuries[a]

	HR Intervention Group				HR Control Group				
	Players at Increased Risk	Injuries	Injured Players	Injury Incidence (95% CI)	Players at Increased Risk	Injuries	Injured Players	Injury Incidence (95% CI)	*P* Value (Control vs Intervention)
Ankle	102	13	10 (10%)	0.6 (0.3-0.9)	107	20	14 (13%)	0.9 (0.5-1.3)	.21
Knee	65	7	6 (9%)	0.5 (0.1-0.9)	66	8	7 (11%)	0.5 (0.2-0.9)	.93
Hamstring	85	23	17 (20%)	1.5 (0.9-2.0)	76	17	14 (18%)	0.9 (0.5-1.4)	.17
Groin	62	11	10 (16%)	0.9 (0.4-1.4)	98	16	13 (13%)	0.7 (0.4-1.1)	.67

[a]The number of players with an increased risk of injury to the different body parts (ankle, knee, hamstring and groin) within the two high risk groups and the number of injuries that occurred to the same body part among these players. HR, high risk; LR, low risk; CI, confidence interval.

control group compared with the 2 other groups (RR, 0.49; 95% CI, 0.33-0.71 vs the HR control group; RR, 0.53; 95% CI, 0.36-0.77 vs the HR intervention group). However, no difference was seen between the HR intervention group and the HR control group (RR, 0.93; 95% CI, 0.71-1.21).

When the players in the HR intervention and HR control groups with increased risk of injury were compared, we found no significant differences in the risk of injury to the body part in question between the 2 groups for any category (ankle: RR, 0.64; 95% CI, 0.32-1.29; knee: RR, 0.96; 95% CI, 0.35-2.64; hamstrings: RR, 1.55; 95% CI, 0.83-2.90; and groin: RR, 1.18; 95% CI, 0.55-2.54) (Table 7).

Compliance With the Training Program and Per-Protocol Analysis

Compliance with the training programs in the HR intervention group was poor, with only 27.5% (28 players) in the ankle group and 29.2% (19 players) in the knee group having completed 30 or more training sessions. For the hamstring and groin exercises, compliance was even less, with only 21.1% (12 players) and 19.4% (16 players) completing 20 or more training sessions, respectively. Hence, the compliant (more than 30 exercises for ankle and knee, and more than 20 training sessions for hamstring and groin) groups are small. As many as 15.7% (16 players) reported not having done any ankle exercises; 11.8% (12 players), 1 to 9 exercise sessions; and 24.5% (25 players), 10 to 19 sessions; while 20.6% (21 players) reported having carried out 20 or more sessions, but less than the target number of 30. The corresponding figures for knee exercises were 23.1% (0 exercise sessions reported), 9.2% (1-9 sessions), 13.8% (10-19 sessions), and 24.6% (20-29 sessions). For hamstring exercises, the figures were 63.2% (0 exercise sessions reported), 7.9% (1-9 sessions), and 7.9% (10-19 sessions); and for groin exercises, 67.7% (0 exercise sessions reported), 4.8% (1-9 sessions), and 8.1% (10-19 sessions).

In a per-protocol analysis on ankle injuries, the incidence of ankle injuries in the compliant group, who sustained 3 injuries (2 of 28 injured players), was 0.5 (95% CI, –0.1 to 1.0) injuries per 1000 hours, compared with 0.9 (95% CI, 0.5-1.3) injuries per 1000 hours among players with an increased risk of ankle injuries in the HR control group (RR = 0.51; 95% CI, 0.2-1.7). Similarly, we could not detect any difference in the risk of knee injury between players in the HR intervention group who were compliant with the knee program (0.2 [95% CI, –0.2 to 0.7] injuries per 1000 hours) and the HR players in the HR control group (0.5 [95% CI, 0.2-0.9] injuries per 1000 hours; RR = 0.46; 95% CI, 0.1-3.7). In the same way, no difference was observed in the incidence of hamstring (RR = 0.94; 95% CI, 0.3-3.2) and groin injuries (RR = 1.6; 95% CI, 0.5-5.6) between players in the HR intervention group who were compliant with the respective training programs and the HR control group.

DISCUSSION

The main finding of this study was that, although we were able to identify players with an increased injury risk through a comprehensive questionnaire, there was no effect of the targeted intervention on injury risk. The most likely explanation for this is the low compliance with the exercise programs. With such low compliance in the intervention group (ranging from 20% to 30% for the different exercise programs), no effect could be expected on injury rate.

In contrast to most previous intervention studies, we chose to randomize players individually to the intervention or control group. We relied on the team physical therapists to instruct the players in the intervention program. However, to avoid contamination, the players were asked to do the exercises outside the regular team training sessions—before or after training or at home. The low overall compliance in the intervention group indicates that significant contamination between groups is unlikely to have occurred. As seen in previous studies, the main challenge is getting players in the intervention group to follow preventive training programs, not keeping other players from training.[23] However, a potentially bigger risk of contamination is the fact that 19 of the 31 teams did team-based preventive exercises similar to ours regularly throughout the preseason, and 16 of these reported good training regimens. We could not, of course, keep the teams from carrying out their normal preventive exercises. Although these team-based exercises were done by players in both groups, the fact that players from the control group trained with exercises similar to our intervention exercises does, of course, reduce the potential of showing a positive preventive effect of our intervention and represents a limitation in this study. Moreover, exercises carried out by each player on his own are probably not as effective as when they are carried out under qualified supervision,[30] not just because of a lower compliance, but also because the quality of the exercises performed can not be ensured in the same way. Potentially negative factors such as initial muscle soreness or eventual boredom could possibly be overcome more effectively in a group training session with a qualified instructor.

Because the compliance was low, the statistical power is also too low to assess the effect of the training programs in the subgroups that did follow the training protocol (ie, through the per-protocol analyses). The 4 programs used were selected either because there was evidence from previous prevention studies to indicate that they are effective or because they have been shown to be effective as rehabilitation exercises after injury. To prevent ankle and knee injuries, various forms of balance-training exercises have been shown to be effective in other study populations.[8,10,15,20,21,26,31,32] Strain injuries to the hamstrings have been effectively prevented through eccentric strength training, such as that used in the present study.[4,7,16,22] A program of strength training and core stability exercises has been shown to be highly effective in the treatment of long-standing groin pain in a population consisting mainly of soccer players.[16] This program formed the basis for the present program, but because we thought it would be unrealistic to implement the entire groin program, we prescribed an abbreviated 10- to 15-minute session to increase compliance. In other words, each of the program components were based on studies indicating their effect in prevention or rehabilitation of the 4 main injury types. However, previous injury as a risk factor is not fully understood; it may be that ankles and knees are not fully restored structurally or functionally. Although the injury prevention literature supports several different exercises, there is limited evidence that reinjuries can be prevented through the same exercises. We do not know which exercises should be chosen to prevent reinjuries and which have potential for primary prevention of the same injury types.

It is possible that the compliant players may have benefited from the programs if they had carried out more sessions. We know that a certain minimum of exercise must be performed before an effect may be expected.[23] For the purposes of data analysis, we suggested that at least 30 exercises (20 for hamstring and groin) needed to be carried out. However, this number is arbitrary, as there is no evidence on the dose-effect relationship for any exercise program to prevent injuries.

Although the intervention was ineffective, this study demonstrates that the players who had the most to gain from preventive exercises could be identified. The risk of injury was approximately twice as high among athletes with a history of previous injury and/or reported reduced function. This identification was achieved through the use of a simple questionnaire only, and the addition of more elaborate functional tests did not increase the predictive value of the screening (data not shown). The rationale for the approach used, employing a self-completed questionnaire, provided the potential for expanding the range of application of the athlete screening process. The questionnaire represents a cost-effective means of player screening, which could also be done using Web-based solutions. In this way, teams and players with no medical staff could do a self-test in the preseason to find out whether they have an increased risk of injuries.

The increased risk associated with a history of previous injury and reduced function also has other implications. One is that preventing the first injury should be a high priority, to keep players from entering the vicious cycle of repeated injuries to the same body part. This cannot be achieved only at the team level; more research is needed and effective injury prevention may also involve changes to the rules of the game and more specific training of referees.[1,2] The most likely explanation for previous injury being such a consistent risk factor for reinjuries is that the joints or muscles in question are not fully restored structurally and/or functionally. Based on this, it seems reasonable to suggest that one thing teams can do, even at lower levels of play, is to focus on improving rehabilitation after injury and implementing adequate return-to-play guidelines. Players with reduced function after previous injury should undergo a structured rehabilitation program until full function is established. However, it remains to be proven whether this would reduce injury risk significantly. The present study also shows that this cannot be left to the players themselves; adequate supervision is necessary.

One limitation of this study is the difference in physical therapist contact between the HR intervention players and the other groups. To instruct in the intervention exercises, the physical therapist became well acquainted with each of the intervention players, and not always to the same extent with the other players on the team. Thus, there was a potential for a bias in injury reporting, as the same physical therapist also was responsible for reporting injuries.

CONCLUSION

We were able to identify the players with an increased risk of injury through a questionnaire on previous injuries and joint and muscle function only. However, the introduction of individual specific preventive training programs did not affect the injury risk in this intervention, most likely due to a low compliance with the training programs prescribed.

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REFERENCES

1. Andersen TE, Arnason A, Engebretsen L, Bahr R. Mechanisms of head injuries in elite football. *Br J Sports Med.* 2004;38:690-696.
2. Andersen TE, Floerenes TW, Arnason A, Bahr R. Video analysis of the mechanisms for ankle injuries in football. *Am J Sports Med.* 2004;32:69S-79S.
3. Andersen TE, Tenga A, Engebretsen L, Bahr R. Video analysis of injuries and incidents in Norwegian professional football. *Br J Sports Med.* 2004;38:626-631.

4. Arnason A, Andersen TE, Holme I, Engebretsen L, Bahr R. Prevention of hamstring strains in elite soccer: an intervention study. *Scand J Med Sci Sports.* 2007 Mar 12 [Epub ahead of print].
5. Arnason A, Gudmundsson A, Dahl HA, Johannsson E. Soccer injuries in Iceland. *Scand J Med Sci Sports.* 1996;6:40-45.
6. Arnason A, Sigurdsson SB, Gudmundsson A, Holme I, Engebretsen L, Bahr R. Risk factors for injuries in football. *Am J Sports Med.* 2004; 32:5S-16S.
7. Askling C, Karlsson J, Thorstensson A. Hamstring injury occurrence in elite soccer players after preseason strength training with eccentric overload. *Scand J Med Sci Sports.* 2003;13:244-250.
8. Caraffa A, Cerulli G, Projetti M, Aisa G, Rizzo A. Prevention of anterior cruciate ligament injuries in soccer. A prospective controlled study of proprioceptive training. *Knee Surg Sports Traumatol Arthrosc.* 1996;4:19-21.
9. Dvorak J, Junge A. Football injuries and physical symptoms: a review of the literature. *Am J Sports Med.* 2000;28:S3-S9.
10. Ekstrand J, Gillquist J, Liljedahl SO. Prevention of soccer injuries: supervision by doctor and physiotherapist. *Am J Sports Med.* 1983;11:116-120.
11. Ekstrand J, Gillquist J, Moller M, Oberg B, Liljedahl SO. Incidence of soccer injuries and their relation to training and team success. *Am J Sports Med.* 1983;11:63-67.
12. Ekstrand J, Tropp H. The incidence of ankle sprains in soccer. *Foot Ankle.* 1990;11:41-44.
13. Fuller CW, Ekstrand J, Junge A, et al. Consensus statement on injury definitions and data collection procedures in studies of football (soccer) injuries. *Clin J Sport Med.* 2006;16:97-106.
14. Hawkins RD, Fuller CW. A prospective epidemiological study of injuries in four English professional football clubs. *Br J Sports Med.* 1999;33:196-203.
15. Heidt RS Jr, Sweeterman LM, Carlonas RL, Traub JA, Tekulve FX. Avoidance of soccer injuries with preseason conditioning. *Am J Sports Med.* 2000;28:659-662.
16. Holmich P, Uhrskou P, Ulnits L et al. Effectiveness of active physical training as treatment for long-standing adductor-related groin pain in athletes: randomised trial. *Lancet.* 1999;353:439-443.
17. Inklaar H. Soccer injuries. I: Incidence and severity. *Sports Med.* 1994; 18:55-73.
18. Juma AH. Outline of sport injuries in the V World Youth Championship for FIFA Cup in Saudi Arabia. *Indian J Med Sci.* 1998;52:433-437.
19. Junge A, Dvorak J, Graf-Baumann T, Peterson L. Football injuries during FIFA tournaments and the Olympic Games, 1998-2001: development and implementation of an injury-reporting system. *Am J Sports Med.* 2004;32:80S-89S.
20. Junge A, Rosch D, Peterson L, Graf-Baumann T, Dvorak J. Prevention of soccer injuries: a prospective intervention study in youth amateur players. *Am J Sports Med.* 2002;30:652-659.
21. Mandelbaum BR, Silvers HJ, Watanabe DS, et al. Effectiveness of a neuromuscular and proprioceptive training program in preventing anterior cruciate ligament injuries in female athletes: 2-year follow-up. *Am J Sports Med.* 2005;33:1003-1010.
22. Mjolsnes R, Arnason A, Osthagen T, Raastad T, Bahr R. A 10-week randomized trial comparing eccentric vs. concentric hamstring strength training in well-trained soccer players. *Scand J Med Sci Sports.* 2004;14:311-317.
23. Myklebust G, Engebretsen L, Braekken IH, Skjolberg A, Olsen OE, Bahr R. Prevention of anterior cruciate ligament injuries in female team handball players: a prospective intervention study over three seasons. *Clin J Sport Med.* 2003;13:71-78.
24. Nielsen AB, Yde J. Epidemiology and traumatology of injuries in soccer. *Am J Sports Med.* 1989;17:803-807.
25. Nilsson S, Roaas A. Soccer injuries in adolescents. *Am J Sports Med.* 1978;6:358-361.
26. Olsen OE, Myklebust G, Engebretsen L, Holme I, Bahr R. Exercises to prevent lower limb injuries in youth sports: cluster randomised controlled trial. *BMJ.* 2005;330:449.
27. Roos EM, Brandsson S, Karlsson J. Validation of the foot and ankle outcome score for ankle ligament reconstruction. *Foot Ankle Int.* 2001;22:788-794.
28. Roos EM, Roos HP, Lohmander LS, Ekdahl C, Beynnon BD. Knee Injury and Osteoarthritis Outcome Score (KOOS)—development of a self-administered outcome measure. *J Orthop Sports Phys Ther.* 1998;28:88-96.
29. Schmidt-Olsen S, Jorgensen U, Kaalund S, Sorensen J. Injuries among young soccer players. *Am J Sports Med.* 1991;19: 273-275.
30. Soderman K, Werner S, Pietila T, Engstrom, Alfredson H. Balance board training: prevention of traumatic injuries of the lower extremities in female soccer players? A prospective randomized intervention study. *Knee Surg Sports Traumatol Arthrosc.* 2000;8: 356-363.
31. Surve I, Schwellnus MP, Noakes T, Lombard C. A fivefold reduction in the incidence of recurrent ankle sprains in soccer players using the Sport-Stirrup orthosis. *Am J Sports Med.* 1994;22:601-606.
32. Tropp H, Askling C, Gillquist J. Prevention of ankle sprains. *Am J Sports Med.* 1985;13:259-262.
33. Walden M, Hagglund M, Ekstrand J. Injuries in Swedish elite football—a prospective study on injury definitions, risk for injury and injury pattern during 2001. *Scand J Med Sci Sports.* 2005;15:118-125.
34. Walden M, Hagglund M, Ekstrand J. UEFA Champions League study: a prospective study of injuries in professional football during the 2001-2002 season. *Br J Sports Med.* 2005;39:542-546.

Erratum (Paper I)

There is an error in table 7, paper I. The columns for hamstring in table 7 had been misplaced in the wrong column: 76 players were at increased risk in the HR intervention group, while 85 in the HR control group. This caused an error in the percentage injured players, but the injury incidence and p-value are correctly calculated. The correct numbers are highlighted in **bold** text. In the text, the correct numbers were used. This error does not influence the results in any way.

Table 7. Intention-to-treat analysis for ankle, knee, hamstring and groin injuries. The number of players with an increased risk of injury to the different body parts (ankle, knee, hamstring and groin) within the two high risk groups and the number of injuries that occurred to the same body part among these players.

	HR intervention group				HR control group				
	Players at increased risk	Injuries	Injured players	Injury incidence	Players at increased risk	Injuries	Injured players	Injury incidence	P-value (control vs. intervention)
Ankle	102	13	10 (10%)	0.6 [0.3-0.9]	107	20	14 (13%)	0.9 [0.5-1.3]	0.21
Knee	65	7	6 (9%)	0.5 [0.1-0.9]	66	8	7 (11%)	0.5 [0.2-0.9]	0.93
Hamstring	**76**	23	17 (**22**%)	1.5 [0.9-2.0]	**85**	17	14 (**16**%)	0.9 [0.5-1.4]	0.17
Groin	62	11	10 (16%)	0.9 [0.4-1.4]	98	16	13 (13%)	0.7 [0.4-1.1]	0.67

OSLO SPORTS TRAUMA RESEARCH CENTER
ANKLE INJURY SCREENING QUESTIONNAIRE

1A - Information on previous ankle injuries

LEFT ANKLE

Number of previous acute ankle injuries (sprains):
☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ >5

If you answered "0" above, skip the next 3 questions regarding the left ankle and continue at the next section, 1B.

Time since most recent injury:
☐ 0-6 months ☐ 6-12 months ☐ 1-2 y ☐ >2 y

For how long were you unable to fully play/train?
☐ 1-3 days ☐ 4-7 days ☐ 1-4 weeks ☐ >4 weeks

Do you usually use any form of ankle protection?
☐ No
☐ Tape If tape: ☐ Always ☐ Sometimes
☐ Orthosis/brace
If orthosis: ☐ Always ☐ Sometimes

RIGHT ANKLE

Number of previous acute ankle injuries (sprains):
☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ >5

If you answered "0" above, skip the next 3 questions regarding the right ankle and continue at the next section, 1B.

Time since most recent injury:
☐ 0-6 months ☐ 6-12 months ☐ 1-2 y ☐ >2 y

For how long were you unable to fully play/train?
☐ 1-3 days ☐ 4-7 days ☐ 1-4 weeks ☐ >4 weeks

Do you usually use any form of ankle protection?
☐ No
☐ Tape If tape: ☐ Always ☐ Sometimes
☐ Orthosis/brace
If orthosis: ☐ Always ☐ Sometimes

FAOS form (1) for both left and right ankle.

2A - Information on previous knee injuries

LEFT KNEE

Number of previous acute knee injuries (sprains):
☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ >5

If you answered ”0” above, skip the next 6 questions regarding the left knee and continue at the next section, 2B.

Time since most recent injury:
☐ 0-6 months ☐ 6-12 months ☐ 1-2 y ☐ >2 y

For how long were you unable to fully play/train?
☐ 1-3 days ☐ 4-7 days ☐ 1-4 weeks ☐ >4 weeks

Do you usually use any form of knee protection?
☐ No
☐ Tape ☐ Always ☐ Sometimes
☐ Orthosis/brace ☐ Always ☐ Sometimes

If you have a previous knee injury, what kind of injury was it? Tick more than one box if you have had several injuries

Have you injured the meniscus:
☐ Yes – if so; which one?
☐ Medial ☐ Lateral
☐ Do not know

Have you injured any ligaments:
☐ Yes – if so; which one?
☐ Medial ☐ Lateral
☐ Do not know

Have you injured any cruciate ligaments:
☐ Yes – if so; which one?
☐ Anterior (ACL) ☐ Posterior (PCL)
☐ Do not know

Have you had any fractures close to the knee?
☐ Yes – if so; where?
☐ Patella
☐ Femur
☐ Tibia
☐ Fibula
☐ Do not know

Have you had a cartilage injury of the knee?
☐ Yes – if so; which compartment?
☐ Medial ☐ Lateral
☐ Do not know

RIGHT KNEE

Number of previous acute knee injuries (sprains):
☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ >5

If you answered ”0” above, skip the next 6 questions regarding the right knee and continue at the next section, 2B.

Time since most recent injury:
☐ 0-6 months ☐ 6-12 months ☐ 1-2 y ☐ >2 y

For how long were you unable to fully play/train?
☐ 1-3 days ☐ 4-7 days ☐ 1-4 weeks ☐ >4 weeks

Do you usually use any form of knee protection?
☐ No
☐ Tape ☐ Always ☐ Sometimes
☐ Orthosis/brace ☐ Always ☐ Sometimes

If you have a previous knee injury, what kind of injury was it? Tick more than one box if you have had several injuries

Have you injured the meniscus:
☐ Yes – if so, which one?
☐ Medial ☐ Lateral
☐ Do not know

Have you injured any ligaments:
☐ Yes – if so; which one?
☐ Medial ☐ Lateral
☐ Do not know

Have you injured any cruciate ligaments:
☐ Yes – if so; which one?
☐ Anterior (ACL) ☐ Posterior (PCL)
☐ Do not know

Have you had any fractures close to the knee?
☐ Yes – if so; where?
☐ Patella
☐ Femur
☐ Tibia
☐ Fibula
☐ Do not know

Have you had a cartilage injury of the knee?
☐ Yes – if so; which compartment?
☐ Medial ☐ Lateral
☐ Do not know

KOOS-form (2) for both left and right knee.

3A - Information on previous hamstring strains

LEFT SIDE

Number of previous acute hamstring strains:
☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ >5

If you answered "0" above, skip the next 3 questions regarding the left hamstrings and continue at the next section, 3B.

Time since most recent injury:
☐ 0-6 months ☐ 6-12 months ☐ 1-2 y ☐ >2 y

For how long were you unable to fully play/train?
☐ 1-3 days ☐ 4-7 days ☐ 1-4 weeks ☐ >4 weeks

Have you missed a training/match during the previous season due to symptoms from your hamstrings?
☐ No - never
☐ Yes
☐ Rarely ☐ Sometimes ☐ Often

RIGHT SIDE

Number of previous acute hamstring strains:
☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ >5

If you answered "0" above, skip the next 3 questions regarding the right hamstrings and continue at the next section, 3B.

Time since most recent injury:
☐ 0-6 months ☐ 6-12 months ☐ 1-2 y ☐ >2 y

For how long were you unable to fully play/train?
☐ 1-3 days ☐ 4-7 days ☐ 1-4 weeks ☐ >4 weeks

Have you missed a training/match during the previous season due to symptoms from your hamstrings?
☐ No - never
☐ Yes
☐ Rarely ☐ Sometimes ☐ Often

INSTRUCTIONS: This survey asks for your view about your hamstrings. This information will help us keep track of how you feel about your hamstrings and how you function in training, match and daily life.

Please respond to every question by ticking the appropriate box, only one box for each question. If you are unsure about how to answer a question, please give the best answer you can. Remember to answer both for the right and the left hamstrings.

Symptoms

These questions should be answered thinking of the symptoms from your posterior thigh/hamstrings during the **last week**.

1- Have you experienced soreness/stiffness/had complaints from your posterior thigh/hamstrings?

Left side:					Right side:				
Never	Rarely	Sometimes	Often	Always	Never	Rarely	Sometimes	Often	Always
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Soreness

The following questions cover soreness in the posterior thigh region. Report the degree of soreness that you have experienced from your posterior thigh/hamstrings during a typical week.

2- How sore is your posterior thigh after training?

Left side:					Right side:				
Nothing at all	A little	Moderate	A lot	Very much	Nothing at all	A little	Moderate	A lot	Very much
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

3- How sore is your posterior thigh during training?

Left side:					Right side:				
Nothing at all	A little	Moderate	A lot	Very much	Nothing at all	A little	Moderate	A lot	Very much
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

4- How sore is your posterior thigh when you wake up in the morning?

Left side:					Right side:				
Nothing at all	A little	Moderate	A lot	Very much	Nothing at all	A little	Moderate	A lot	Very much
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

5- How sore is your posterior thigh if you have been sitting still for a while during the day?

Left side:					Right side:				
Nothing at all	A little	Moderate	A lot	Very much	Nothing at all	A little	Moderate	A lot	Very much
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Pain

6-How often do you experience pain from your posterior thigh?

Left side:

Never	Rarely	Sometimes	Often	Always
☐	☐	☐	☐	☐

Right side:

Never	Rarely	Sometimes	Often	Always
☐	☐	☐	☐	☐

7-Do you often sustain small strains in your posterior thigh that resolve quickly?

Left side:

Never	Rarely	Sometimes	Often	Always
☐	☐	☐	☐	☐

Right side:

Never	Rarely	Sometimes	Often	Always
☐	☐	☐	☐	☐

Report the degree of pain that you have felt from your posterior thigh/hamstrings during the last week when performing the following activities:

8-Stretching the posterior thigh/hamstrings

Left side:

No pain	A little	Moderate	Considerable	Very painful
☐	☐	☐	☐	☐

Right side:

No pain	A little	Moderate	Considerable	Very painful
☐	☐	☐	☐	☐

9-Walking up a ladder/stairs (double steps)

Left side:

No pain	A little	Moderate	Considerable	Very painful
☐	☐	☐	☐	☐

Right side:

No pain	A little	Moderate	Considerable	Very painful
☐	☐	☐	☐	☐

10-Jogging

Left side:

No pain	A little	Moderate	Considerable	Very painful
☐	☐	☐	☐	☐

Right side:

No pain	A little	Moderate	Considerable	Very painful
☐	☐	☐	☐	☐

11-Changing direction while running

Left side:

No pain	A little	Moderate	Considerable	Very painful
☐	☐	☐	☐	☐

Right side:

No pain	A little	Moderate	Considerable	Very painful
☐	☐	☐	☐	☐

12-Accelerating

Left side:

No pain	A little	Moderate	Considerable	Very painful
☐	☐	☐	☐	☐

Right side:

No pain	A little	Moderate	Considerable	Very painful
☐	☐	☐	☐	☐

13-Braking speed after sprinting

Left side:

No pain	A little	Moderate	Considerable	Very painful
☐	☐	☐	☐	☐

Right side:

No pain	A little	Moderate	Considerable	Very painful
☐	☐	☐	☐	☐

Function, daily living and sports

The following questions concern your physical function. For each of the following activities, please indicate the degree of difficulty you have experienced in the last week due to your posterior thigh/hamstrings.

14-Running

Left side:					Right side:				
Nothing at all	A little	Moderate	A lot	Very much	Nothing at all	A little	Moderate	A lot	Very much
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

15-Jumping

Left side:					Right side:				
Nothing at all	A little	Moderate	A lot	Very much	Nothing at all	A little	Moderate	A lot	Very much
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

16-Accelerating

Left side:					Right side:				
Nothing at all	A little	Moderate	A lot	Very much	Nothing at all	A little	Moderate	A lot	Very much
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

17- Braking speed after sprinting

Left side:					Right side:				
Nothing at all	A little	Moderate	A lot	Very much	Nothing at all	A little	Moderate	A lot	Very much
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Quality of life

The following questions concern how problems from your hamstrings restrain you during physical activity. Report the degree of difficulty you have experienced during the last week due to your posterior thigh/hamstrings.

18- In what degree do you trust your hamstrings during physical activity?

Left side:					Right side:				
Totally	A lot	Moderate	To some degree	Not at all	Totally	A lot	Moderate	To some degree	Not at all
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

19-Do you sometimes keep from performing 100% due to concerns of sustaing a hamstring strain?

Left side:					Right side:				
Not at all	To some degree	Moderate	A lot	Totally	Not at all	To some degree	Moderate	A lot	Totally
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

4A - Information on previous acute groin strains

LEFT GROIN

Number of previous acute groin strains:
☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ >5

If you answered "0" above, skip the next 4 questions regarding the left groin and continue at the next section, 4B.

Time since most recent injury:
☐ 0-6 months ☐ 6-12 months ☐ 1-2 y ☐ >2 y

For how long were you unable to fully play/train?
☐ 1-3 days ☐ 4-7 days ☐ 1-4 weeks ☐ >4 weeks

Treatment received for the last injury:
☐ surgery ☐ physiotherapi ☐ none ☐ do not know

Have you had groin surgery? (Gilmore's groin)
☐ No
☐ Yes

RIGHT GROIN

Number of previous acute groin strains:
☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ >5

If you answered "0" above, skip the next 4 questions regarding the right groin and continue at the next section, 4B.

Time since most recent injury:
☐ 0-6 months ☐ 6-12 months ☐ 1-2 y ☐ >2 y

For how long were you unable to fully play/train?
☐ 1-3 days ☐ 4-7 days ☐ 1-4 weeks ☐ >4 weeks

Treatment received for the last injury:
☐ surgery ☐ physiotherapi ☐ none ☐ do not know

Have you had groin surgery? (Gilmore's groin)
☐ No
☐ Yes

INSTRUCTIONS: This survey asks for your view about your groin function. This information will help us keep track of how you feel about your groin and how you function in training, match and daily life.

Please respond to every question by ticking the appropriate box, only one box for each question. If you are unsure about how to answer a question, please give the best answer you can. Remember to answer both for the right and the left groin.

Symptoms

These questions should be answered thinking of the symptoms from your groin region during the **last week**.

1- Have you experienced soreness/stiffness/had complaints from your groin?

Left side:

Never	Rarely	Sometimes	Often	Always
☐	☐	☐	☐	☐

Right side:

Never	Rarely	Sometimes	Often	Always
☐	☐	☐	☐	☐

Soreness

The following questions cover soreness in the groin. Report the degree of soreness that you have experienced from your groin during **a typical week**.

2- How sore is your groin after training?

Left side:

Nothing at all	A little	Moderate	A lot	Very much
☐	☐	☐	☐	☐

Right side:

Nothing at all	A little	Moderate	A lot	Very much
☐	☐	☐	☐	☐

3- How sore is your groin during training?

Left side:

Nothing at all	A little	Moderate	A lot	Very much
☐	☐	☐	☐	☐

Right side:

Nothing at all	A little	Moderate	A lot	Very much
☐	☐	☐	☐	☐

4-How sore is your groin when you wake up in the morning?

Left side:

Nothing at all	A little	Moderate	A lot	Very much
☐	☐	☐	☐	☐

Right side:

Nothing at all	A little	Moderate	A lot	Very much
☐	☐	☐	☐	☐

5- How sore is your groin if you have been sitting still for a while during the day?

Left side:

Nothing at all	A little	Moderate	A lot	Very much
☐	☐	☐	☐	☐

Right side:

Nothing at all	A little	Moderate	A lot	Very much
☐	☐	☐	☐	☐

Pain

6-How often do you experience pain from your groin?

Left side:					Right side:				
Never	Rarely	Sometimes	Often	Always	Never	Rarely	Sometimes	Often	Always
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

7-Do you often sustain small strains in your groin that heal quickly?

Left side:					Right side:				
Never	Rarely	Sometimes	Often	Always	Never	Rarely	Sometimes	Often	Always
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Report the degree of pain that you have felt from your groin during the last week in the following activities:

8-Stretching of the groin

Left side:					Right side:				
No pain	A little	Moderate	Considerable	Very painful	No pain	A little	Moderate	Considerable	Very painful
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

9-Walk up a ladder/stairs (double steps)

Left side:					Right side:				
No pain	A little	Moderate	Considerable	Very painful	No pain	A little	Moderate	Considerable	Very painful
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

10-Jogging

Left side:					Right side:				
No pain	A little	Moderate	Considerable	Very painful	No pain	A little	Moderate	Considerable	Very painful
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

11-Change of direction while running

Left side:					Right side:				
No pain	A little	Moderate	Considerable	Very painful	No pain	A little	Moderate	Considerable	Very painful
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

12-Acceleration

Left side:					Right side:				
No pain	A little	Moderate	Considerable	Very painful	No pain	A little	Moderate	Considerable	Very painful
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

13-Braking speed after sprinting

Left side:					Right side:				
No pain	A little	Moderate	Considerable	Very painful	No pain	A little	Moderate	Considerable	Very painful
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

14-Standing on one leg

Left side:

No pain	A little	Moderate	Considerable	Very painful
☐	☐	☐	☐	☐

Right side:

No pain	A little	Moderate	Considerable	Very painful
☐	☐	☐	☐	☐

15-Making long passes/hard shots

Left side:

No pain	A little	Moderate	Considerable	Very painful
☐	☐	☐	☐	☐

Right side:

No pain	A little	Moderate	Considerable	Very painful
☐	☐	☐	☐	☐

16-Making short passes

Left side:

No pain	A little	Moderate	Considerable	Very painful
☐	☐	☐	☐	☐

Right side:

No pain	A little	Moderate	Considerable	Very painful
☐	☐	☐	☐	☐

17-Keeping your balance on one leg (as when volleying)

Left side:

No pain	A little	Moderate	Considerable	Very painful
☐	☐	☐	☐	☐

Right side:

No pain	A little	Moderate	Considerable	Very painful
☐	☐	☐	☐	☐

18-Shooting when one leg is lifted high to reach the ball (volley)

Left side:

No pain	A little	Moderate	Considerable	Very painful
☐	☐	☐	☐	☐

Right side:

No pain	A little	Moderate	Considerable	Very painful
☐	☐	☐	☐	☐

Function, daily living and sports

The following questions concern your physical function. For each of the following activities please indicate the degree of difficulty you have experienced in the last week because of your groin.

19-Running

Left side:

Nothing at all	A little	Moderate	A lot	Very much
☐	☐	☐	☐	☐

Right side:

Nothing at all	A little	Moderate	A lot	Very much
☐	☐	☐	☐	☐

20-Jumping

Left side:

Nothing at all	A little	Moderate	A lot	Very much
☐	☐	☐	☐	☐

Right side:

Nothing at all	A little	Moderate	A lot	Very much
☐	☐	☐	☐	☐

21-Acceleration

Left side:

Nothing at all	A little	Moderate	A lot	Very much
☐	☐	☐	☐	☐

Right side:

Nothing at all	A little	Moderate	A lot	Very much
☐	☐	☐	☐	☐

22- Braking speed after sprinting

Left side:

Nothing at all	A little	Moderate	A lot	Very much
☐	☐	☐	☐	☐

Right side:

Nothing at all	A little	Moderate	A lot	Very much
☐	☐	☐	☐	☐

23-Making long passes/hard shots

Left side:

Nothing at all	A little	Moderate	A lot	Very much
☐	☐	☐	☐	☐

Right side:

Nothing at all	A little	Moderate	A lot	Very much
☐	☐	☐	☐	☐

24-Making short passes

Left side:

Nothing at all	A little	Moderate	A lot	Very much
☐	☐	☐	☐	☐

Right side:

Nothing at all	A little	Moderate	A lot	Very much
☐	☐	☐	☐	☐

25- Keeping your balance on one leg (as when volleying)

Left side:

Nothing at all	A little	Moderate	A lot	Very much
☐	☐	☐	☐	☐

Right side:

Nothing at all	A little	Moderate	A lot	Very much
☐	☐	☐	☐	☐

26- Shooting when one leg is lifted high to reach the ball (volley)

Left side:

Nothing at all	A little	Moderate	A lot	Very much
☐	☐	☐	☐	☐

Right side:

Nothing at all	A little	Moderate	A lot	Very much
☐	☐	☐	☐	☐

Quality of life

The following questions concern how your problems from your groin limit you during physical activity. Report the degree of difficulty you have experienced during the last week because of your groin.

27- In what degree do you trust your groin during physical activity?

Left side:

Totally	A lot	Moderate	To some degree	Not at all
☐	☐	☐	☐	☐

Right side:

Totally	A lot	Moderate	To some degree	Not at all
☐	☐	☐	☐	☐

28-Do you sometimes limit yourself from performing 100% due to concerns of sustaining a groin strain?

Left side:

Not at all	To some degree	Moderate	A lot	Totally
☐	☐	☐	☐	☐

Right side:

Not at all	To some degree	Moderate	A lot	Totally
☐	☐	☐	☐	☐

29-Have you changed your way of playing (for instance do you shoot less) due to complaints from your groin?

Left side:

Not at all	To some degree	Moderate	A lot	Totally
☐	☐	☐	☐	☐

Right side:

Not at all	To some degree	Moderate	A lot	Totally
☐	☐	☐	☐	☐

References

(1) Roos EM, Brandsson S, Karlsson J. Validation of the foot and ankle outcome score for ankle ligament reconstruction. Foot Ankle Int 22: 788-94, 2001.

(2) Roos EM, Roos HP, Lohmander LS, Ekdahl C, Beynnon BD. Knee Injury and Osteoarthritis Outcome Score (KOOS)--development of a self-administered outcome measure. J Orthop Sports Phys Ther 28: 88-96, 1998.

Scoring instructions for the Hamstring and Groin function scores

- Each item is scored from 0 (best score) to 4 (worst score). For example, for the item “How often do you experience pain from your posterior thigh?” a score of 0 is given for “Never”, 1 for “Rarely”, 2 for “Sometimes”, 3 for “Often”, and 4 for “Always”.

- Sub-scores are calculated for each of the five main categories “Symptoms”, “Soreness”, “Pain”, “Function, daily living and sports” and “Quality of life”. The score is calculated in percent of the maximum score in each category, i.e. players without any complaints/symptoms would score 100 on each category.

- If desired, the total score is calculated as the mean of the five subscore percentages. For example, a patient scoring 50% of the maximum subscore for “Symptoms”, 38% on “Soreness”, 47% on “Pain”, 25% on “Function, daily living and sports” and 50% on “Quality of life” would receive a total score of 42.

Paper II

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Intrinsic risk factors for acute ankle injuries among male soccer players: a prospective cohort study

A. H. Engebretsen[1], G. Myklebust[1], I. Holme[1], L. Engebretsen[1,2], R. Bahr[1]

[1]Oslo Sports Trauma Research Center, Norwegian School of Sports Sciences, N-0806 Oslo, Norway, [2]Department of Orthopaedic Surgery, Ulleval University Hospital and Medical School, University of Oslo, N-0407 Oslo, Norway
Corresponding author: A. H. Engebretsen, MD, Oslo Sports Trauma Research Center, Norwegian School of Sports Science, PO Box 4014, Ullevål Stadion, N-0806 Oslo, Norway. Tel: +47 23 26 23 57, Fax: 23 26 23 07, E-mail: anders.engebretsen@nih.no

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This prospective cohort study was conducted to identify risk factors for acute ankle injuries among male soccer players. A total of 508 players representing 31 amateur teams were tested during the 2004 pre-season through a questionnaire on previous injury and function score (foot and ankle outcome score; FAOS), functional tests (balance tests on the floor and a balance mat) and a clinical examination of the ankle. Generalized estimating equations were used in univariate analyses to identify candidate risk factors, and factors with a *P*-value <0.10 were then examined in a multivariate model. During the season, 56 acute ankle injuries, affecting 46 legs (43 players), were registered. Univariate analyses identified a history of previous acute ankle injuries [odds ratio (OR) per previous injury: 1.25, 95% confidence interval (CI) 1.09–1.43] and the FAOS subscore "Pain" (OR for a 10-point difference in score: 0.81, 95% CI 0.62–1.04) as candidate risk factors. In a multivariate analysis, only the number of previous acute ankle injuries proved to be a significant (adjusted OR per previous injury: 1.23; 95% CI 1.06–1.41, $P = 0.005$) predictor of new injuries. Function scores, functional tests and clinical examination could not independently identify players at an increased risk in this study.

The ankle joint is one of the most common injury locations in sports in general and soccer in particular. The injury incidence ranges from 1.7 to 4.5 injuries per 1000 playing hours, accounting for 11–25% of all acute injuries (Ekstrand & Tropp, 1990; Árnason et al., 1996; Juma, 1998; Hawkins & Fuller, 1999; Andersen et al., 2004; Junge et al., 2004). An ankle sprain may leave an athlete out of play for several weeks, and in many cases full recovery takes much longer. Injuries to the ankle are therefore a concern.

To possibly prevent new injuries, the specific intrinsic and extrinsic risk factors for the injury type in question must be known (Meeuwisse, 1994). Regarding intrinsic risk factors, it has been suggested that previous injury, especially when rehabilitation is inadequate, places an athlete at an increased risk of suffering an injury to the ankle (Ekstrand & Gillquist, 1983; Tropp et al., 1985; Árnason et al., 2004; Kofotolis et al., 2007). Several other potential risk factors have been tested and suggested as possible predictors of increased risk, however, with limited data on male soccer players. These include a slow reaction time (Taimela et al., 1990; Árnason et al., 2004), personality factors (Taerk, 1977; Lysens et al., 1989; Taimela et al., 1990; Junge et al., 2000; Árnason et al., 2004), age (Backous et al., 1988; Lindenfeld et al., 1994; Ostenberg & Roos, 2000), general joint laxity (Baumhauer et al., 1995; Ostenberg & Roos, 2000; Beynnon et al., 2001), ankle joint laxity (Beynnon et al., 2001) and balance tests (Trojian & McKeag, 2006). Regarding body size measures such as height, weight and body mass index (BMI), the literature is also inconclusive (Backous et al., 1988; Baumhauer et al., 1995; Beynnon et al., 2001; Tyler et al., 2006). Some risk factors have been tested further in intervention studies, and balance training (Tropp et al., 1985) and orthoses (Tropp et al., 1985; Surve et al., 1994) have resulted in significantly fewer ankle sprains, indicating that reduced neuromuscular control is an important risk factor for ankle injuries.

To examine the contribution of the various risk factors of injuries and etiology and to explore their interrelationship, it is necessary to include all in a multivariate analysis (Meeuwisse, 1994). Even though a large number of risk factor studies have been carried out, only a few of them have included multivariate analyses. We therefore planned the present prospective cohort study on soccer players to screen for several potential risk factors for ankle injuries, some of which have not been studied in depth earlier.

Elite players constitute only a small portion of all soccer players, and advanced resources for screening tests are not available for the majority of players. Therefore, one goal of this study was to investigate whether simple screening tests, which are easy to perform and do not require advanced equipment, can be used to identify individuals at risk. In this way, if the questionnaire and balance tests in this study prove useful, teams and players with no medical staff can test themselves in the pre-season to find out whether they have an increased risk of injuries.

We hypothesized that previous ankle injuries, reduced function scores and abnormalities on a clinical examination or balance tests indicating reduced neuromuscular control could predict an increased risk of new ankle injuries. In addition, we included clinical examination and player information such as age, height, weight, BMI and player position to investigate whether there were any correlations between these variables and injury risk.

Hence, the aim of this study was to examine potential intrinsic risk factors for injuries to the ankle in a prospective cohort study among subelite male soccer players.

Methods

Design and participants

This study is based on data from a randomized trial on male amateur soccer players examining the effect of a training program designed to prevent injuries. The design, the intervention program and the results of the study have been described in detail previously in a separate paper (Engebretsen et al., 2008). Because no differences were seen in the injury rates between the intervention and the control groups (Engebretsen et al., 2008), the entire cohort could be used to assess the effect of a number of risk factors assessed at baseline.

A total of 35 teams ($n = 769$ players) from the Norwegian first, second or third division of soccer for men, geographically located in the proximity of Oslo, were invited to participate in the study. The third division teams either won their league or finished as first runners up the previous season, resulting in a relatively homogenous group of teams, even if they competed in three different divisions. Three of the teams ($n = 60$ players) declined the invitation to participate, 177 players did not report for testing, three players did not speak Norwegian and therefore could not complete the questionnaire and four players were excluded for other reasons (Fig. 1). Hence, 244 of the players invited could not be included. In addition, one team ($n = 17$ players) was later excluded because the physiotherapist did not record injuries, resulting in a final sample of 508 players representing 31 teams from three divisions (first division, $n = 7$, 122 players; second division, $n = 16$, 260 players; and third division, $n = 8$, 126 players).

Risk factor screening

The teams were tested for potential risk factors for ankle injuries during the 2004 pre-season, January through March, at the Norwegian School of Sport Sciences. Every player

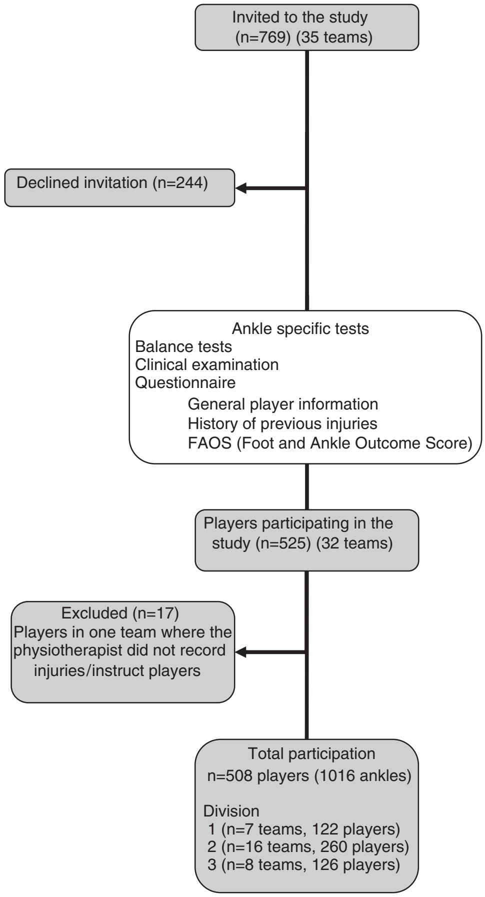

Fig. 1. Flow chart showing movement of numbers of players participating.

capable (not injured at the time) completed single leg balance tests for both legs, both on a balance mat and on the floor, a clinical examination and a questionnaire.

For the balance tests players were asked to stand barefoot on one straight leg, keeping his arms crossed across the chest and his other leg bent 90° at the knee, and only using the ankle joint to correct his balance. Both balance tests (Fig. 2(a) and (b)) were scored in the same manner (quantitatively and qualitatively), in five categories:

- 5 points (maximum score): The player can maintain his balance for 60 s with eyes open and for an additional 15 s with eyes closed, always using an ankle strategy only to maintain his balance.
- 4 points: The player can maintain his balance for 60 s with eyes open, using an ankle strategy only for at least 45 s of this period.
- 3 points: The player is able to maintain his balance for 60 s with eyes open, but needs to use body parts other than the ankle joint (knee, hip, torso, and arms) to correct his balance for more than 15 s of this period.

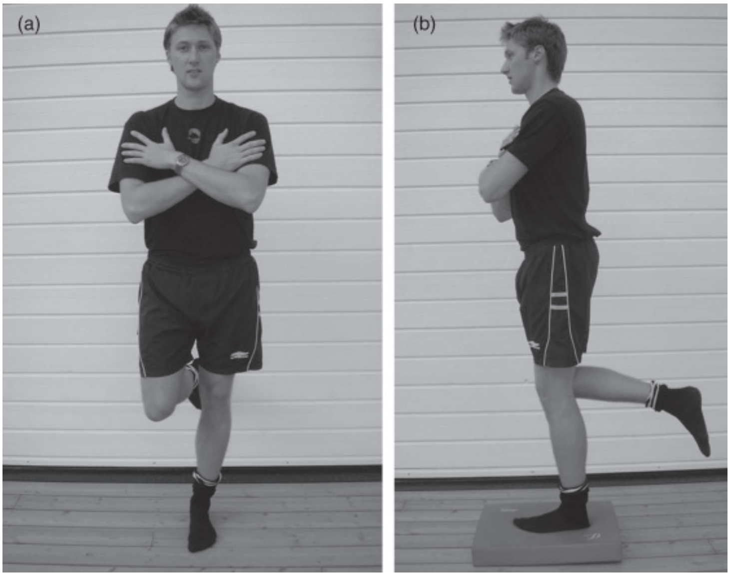

Fig. 2. Front (a) and side (b) view of balance test on the floor and a balance mat, respectively. Players were asked to stand barefoot on one straight leg, keeping his arms crossed across the chest and his other leg bent 90° at the knee, and only using the ankle joint to correct his balance.

- 2 points: The player can balance for 60 s but needs to use the upper body and touch the floor with his other foot at times to correct imbalance.
- 1 point: The player cannot manage to balance on one leg for more than short periods of time.

The clinical testing of the players was performed by a group of 10 sports physical therapists and sports physicians who were blinded to any injury history. Both legs were examined for foot type (normal, pes planus, pes cavus, splayed forefoot), standing rearfoot alignment (normal, valgus), hallux position (normal, valgus), anterior drawer (normal, pathologic) and range of motion for supination, pronation (measured in degrees with the ankle at 10° of plantar flexion) and dorsiflexion.

The players also completed a questionnaire in two parts, where the first part covered general player information (age, height, body mass index, position on the field, number of junior or senior national team matches played, level of play this season and level of play the previous season), and a history of previous injuries (number, severity, nature and number of months since the most recent ankle injury, use of protective gear such as tape or brace and whether the most recent injury had caused the player to miss matches). The second part was a function score for the ankle (foot and ankle outcome score; FAOS) (Roos et al., 2001) translated into Norwegian. This form consists of five major parts (symptoms, pain, activities of daily living, function in sports and recreation, quality of life) and is scored by calculating the mean value of the five parts in percent of the total possible score, where 100% is the maximal and 0% the lowest score.

In addition, a similar screening was carried out for risk factors for hamstring, knee and groin injuries. The data from these tests will be reported in separate papers.

Injury reporting

Each team was supplied with a physiotherapist who was responsible for reporting injuries for all the players on the team throughout the pre-season and the season. An injury was defined as any physical complaint sustained by a player that resulted from a soccer match or soccer training, forcing the player to miss or unable to take full part in future soccer training or match play ("time-loss" injury). Acute injuries were defined as injuries with a sudden onset associated with a known trauma, whereas overuse injuries were those with a gradual onset without any known trauma. Two of the authors were blinded to all other information regarding risk factors and categorized all injuries based on the injury reports from the physiotherapist. For the purpose of the present paper, an injury was classified as an ankle sprain if it was recorded as an acute injury of the ankle ligaments. Injuries were classified into three severity categories according to the time it took until the player was fully fit to take part in all types of organized soccer play: minor (1–7 days), moderate (8–28 days) and major (>28 days). The head coach for every team registered each player's participation in training and the number of minutes played in matches.

Most of the teams from the first and second division already had a physical therapist working with the team. In cases where there was no physical therapist attached to the team, we provided them with one. However, the physiotherapist was not required to be present at every training session and match; the degree of follow-up therefore varied from team to team participating in the study.

Reliability testing

Interobserver reliability tests were carried out by different test personnel for both the clinical examination and the single leg balance test by having the same player repeat the same test with different personnel after he had completed the first test. Each examiner was blinded to the other's results. The same scoring system/clinical forms were used at both stations. The interobserver reliability for the categorical variables in the interpretation of the balance tests and the clinical examination was computed using κ statistics.

Statistical methods

Exposure to matches and training was calculated by adding the individual duration of all training and match play during the season.

For the continuous dependent variable risk factor analyses, where each leg was the unit of analysis, generalized estimating equations (STATA, version 8; STATA, Texas, USA) were used, accounting for total individual exposure during the soccer season and for the fact that the left and right foot belonged to the same player. Logistic regression analyses were used to analyze the relationships between per subject first occurrence of calculated dichotomous injury variables and their risk factors.

All risk factor variables were examined in univariate analyses, and those with a *P*-value <0.10 were investigated further in a multivariate model.

Results

The total incidence of injuries during the season was 4.7 injuries per 1000 playing hours [95% confidence interval (CI) 4.3–5.1], 12.1 (95% CI 10.5–13.7) for match injuries and 2.7 (95% CI 2.4–3.1) for training injuries. The total exposure to match play and training was 108 111 player hours. A total of 56 acute ankle injuries were reported, affecting 46 legs on 43 (8.5%) of the 508 players in the study. The total incidence of acute ankle injuries was 0.5 injuries per 1000 playing hours (95% CI 0.4–0.7), 0.3 injuries per 1000 training hours (95% CI 0.2–0.4) and 1.5 injuries per 1000 match hours (95% CI 0.9–2.0). A total of 34 players sustained one ankle injury, while six and two players sustained two and three injuries, respectively. One player sustained four ankle injuries throughout the season. Of the 56 injuries, 34 occurred on the right side, while 22 were on the left. There were 26 minor injuries (time loss 1–7 days), 22 moderate injuries (8–28 days) and five severe injuries (>28 days). In three cases, information on the duration of time loss was missing.

Interobserver reliabilities for the categorical variables, computed using κ statistics, were 0.40 and 0.19 for balance tests on the floor and mat, respectively. For the clinical examination, κ values were 0.45 (anterior drawer), 0.84 (foot type), 0.91 (standing rearfoot alignment), 1.00 (hallux position) and 1.00 (toe deformity).

Univariate analyses revealed the number of previous acute ankle injuries and the FAOS sub score "Pain" as potential leg-dependent risk factors for acute ankle injuries (Table 1). None of the balance tests, floor or balance mat, or clinical tests were candidates for predicting an increased risk of ankle injury. Additionally, none of the player-dependent factors (age, height, body mass index, position on the field, having played at the junior national team or at the senior national team level, level of play this season or level of play the previous season) were significantly associated with the risk of ankle injury (Table 2).

Risk factors with a *P*-value of <0.10 were then considered as candidates to predict which players are more prone to sustain an acute injury to the ankle. Because these factors may be inter-correlated, a multivariate analysis was performed, and only previous acute ankle injury was found to be a significant risk factor for new acute ankle (Table 3). The importance of this risk factor increases with the number of previous injuries (test of trend, $P=0.001$), and seems to decrease with time since the last injury (test of trend, $P=0.06$).

Discussion

The main finding of this cohort study investigating the potential risk factors for ankle injuries in soccer was that previous ankle injury was the only significant predictor we could identify for new acute ankle injuries. The risk increases with the number of previous injuries and is the highest during the first 6 months after injury. Other candidates for identification of players with an increased risk of acute ankle injuries, such as function scores, balance tests, other player characteristics or a clinical examination, were not significantly associated with injury risk.

Several authors have found previous ankle injuries to be a significant risk factor for new injuries, both in male soccer (Ekstrand & Gillquist, 1983; Tropp et al., 1985; Árnason et al., 2004; Kofotolis et al., 2007) and in male athletes in other sports (Bahr & Bahr, 1997; McKay et al., 2001; McGuine & Keene, 2006; McHugh et al., 2006; Tyler et al., 2006). Árnason et al. (2004) found previous ankle injury to be the only significant risk factor for a new injury to the same ankle in a large cohort study investigating risk factors for soccer injuries. In the same study, lateral instability and a positive anterior drawer test were also correlated with previous injury. In contrast to these findings, Trojian and McKeag (2006) and Hägglund et al. (2006) did not find a history of previous ankle injury to be associated with future ankle sprains. However, a limited number of acute ankle injuries were included in these studies (Árnason et al., 2004; Hägglund et al., 2006; Trojian & McKeag, 2006).

Ankle injuries have been prevented effectively through neuromuscular training, either on a balance board or on a balance mat, in soccer (Tropp et al., 1985; Árnason et al., 1996) and in other sports (Bahr et al., 1997; Olsen et al., 2005; McHugh et al., 2007). It therefore seemed reasonable to suggest that a similar exercise could be used as a screening test to identify players at risk. The literature is limited on the topic, and only two publications have looked at

Table 1. Risk factor analyses where each leg was the unit of analysis, including both continuous (mean ± SEM) and categorical (yes/no) dependent variables

	Current injury,				SD	OR	95% CI	*P*-value
	n	Uninjured (*n* = 970)	Injured (*n* = 46)					
		n/mean ± SEM	*n*/mean ± SEM	% injured				
Previous ankle injury								
Yes	616	582	34	5.5%		1.95	[0.99–3.84]	0.05
No	399	387	12	3.0%		1.00		
Missing	1							
Number of previous injuries*								
Average number		1.6 ± 0.1	2.5 ± 0.3			1.25	[1.09–1.43]	0.001
No previous injury						1.00		
1 injury	219	210	9	4.1%		0.92	[0.44–1.95]	0.84
2 injuries	145	140	5	3.4%		0.74	[0.29–1.91]	0.54
3 injuries	87	83	4	4.6%		1.02	[0.34–2.97]	0.97
4 injuries	45	41	4	8.9%		2.34	[0.78–7.01]	0.13
5 injuries	25	22	3	12.0%		2.58	[0.69–9.59]	0.16
> 5 injuries	95	86	9	9.5%		2.55	[1.17–5.56]	0.02
Time since previous injury (*n* = 1016)†								0.06
Never	399	387	12	3.0%		1.00		
0–6 months	137	124	13	9.5%		2.81	[1.42–5.54]	0.003
6–12 months	114	109	5	4.4%		0.96	[0.37–2.50]	0.93
1–2 years	141	134	7	5.0%		1.10	[0.47–2.56]	0.83
> 2 years	218	209	9	4.1%		0.89	[0.42–1.90]	0.77
Missing	7							
FAOS‡ function score								
Total score	902	93 ± 0.3	91 ± 1.7		9.7	0.83	[0.65–1.06]	0.14
Symptoms	931	88 ± 0.4	86 ± 2.2		12.9	0.87	[0.71–1.07]	0.19
Pain	956	96 ± 0.3	93 ± 1.5		9.2	0.81	[0.62–1.04]	0.10
Activities of daily life	957	98 ± 0.2	97 ± 1.3		6.4	0.89	[0.60–1.32]	0.58
Sport	961	94 ± 0.4	92 ± 2.3		13.2	0.92	[0.75–1.11]	0.38
Quality of life	960	90 ± 0.5	87 ± 3.0		15.3	0.88	[0.75–1.04]	0.13
Testing§								
Balance test, floor	999	4.6 ± 0.02	4.7 ± 0.1		0.55	1.08	[0.79–1.48]	0.64
Balance test, mat	999	3.0 ± 0.02	3.2 ± 0.1		0.90	1.14	[0.84–1.54]	0.41
Clinical examination								
Any pathological findings (*n* = 817)								
Yes	427	407	20	4.7%		1.03	[0.75–1.42]	0.85
No	390	374	16	4.1%		1.00		
Foot type (*n* = 886)								0.78
Normal	568	543	25	4.4%		1.00		
Pes planus	228	221	7	3.1%		0.69	[0.29–1.61]	0.39
Pes cavus	73	68	5	6.8%		1.60	[0.59–4.31]	0.36
Splayed forefoot	17	16	1	5.9%		1.36	[0.17–10.6]	0.77
Standing rearfoot alignment (valgus) (*n* = 864)								
Yes	134	131	3	2.2%		1.00		
No	730	697	33	4.5%		1.86	[0.56–6.24]	0.31
Hallux position (valgus) (*n* = 873)								
Yes	76	72	4	5.3%		1.46	[0.49–4.34]	0.50
No	797	763	34	4.3%		1.00		
Anterior drawer (pathologic) (*n* = 876)								
Yes	138	129	9	6.5%		1.83	[0.85–3.98]	0.13
No	738	698	29	3.9%		1.00		
Supination (degrees)§	886	28.8° ± 0.6 (848)	35.0° ± 4.5 (38)		19.2	1.21	[0.93–1.57]	0.15
Pronation (degrees)§	884	9.2° ± 0.2 (846)	9.5° ± 0.6 (38)		9.2	0.98	[0.48–2.00]	0.95
Dorsal extension (degrees)§	865	10.4° ± 7.3 (827)	10.1° ± 5.3 (38)		10.3	0.94	[0.60–1.48]	0.79

The number of legs in the uninjured and injured groups reflect the number of legs that completed each of the tests.

*Results (OR and 95% CI) are presented per previous injury.

†Results (OR and 95% CI) are presented per category increase.

‡FAOS (foot and ankle outcome score). Roos et al. (2001) All results (OR and 95% CI) are presented for a change of 10 in FAOS score.

§Results (OR and 95% CI) are presented per increase of 1 SD.

Range (mean, minimum – maximum) of continuous variables: FAOS (total score: 93.3, 37.2–100.0), (symptoms: 88.4, 28.6–100.0), (pain: 95.6, 38.9–100.0), (activities of daily life: 98.2, 45.6–100.0), (sport: 94.1, 25.0–100.0), (quality of life: 90.1, 6.3–100.0), balance test on floor (4.6, 1.0–5.0), balance test on mat (3.1, 1.0–5.0), supination (29.1, 0–150), pronation (9.2, 0–30) and dorsal extension (10.3, 0–90).

Comparisons of risk factors between ankles that sustained at least one injury during the following season (''Injured'') and ankles that did not (''Uninjured''). *P*-values are the results from univariate analyses in STATA using generalized estimating equations taking into account the individual exposure and the fact that the left and the right leg belong to the same player.

OR, odds ratio; CI, confidence interval; SD, standard deviation.

Table 2. Risk factor analyses where each player was the unit of analysis, including both continuous (mean ± SEM) and categorical (yes/no) dependent variables

	n	Current injury			SD	OR	95% CI	*P*-value
		Uninjured (*n* = 465)	Injured (*n* = 43)					
		n/mean ± SEM	*n*/mean ± SEM	% injured				
Factor								
Age* (years)	500	24.0 ± 0.2 (458)	24.0 ± 0.6 (42)		4.2	1.00	[0.85–1.18]	0.99
Height* (cm)	497	181.4 ± 0.3 (455)	181.0 ± 1.0 (42)		6.3	0.93	[0.68–1.27]	0.66
Weight* (kg)	493	78.0 ± 1.1 (450)	77.9 ± 0.4 (43)		8.0	1.01	[0.74–1.38]	0.94
BMI* (kg/m)	486	23.7 ± 0.1 (444)	23.8 ± 0.2 (42)		2.1	1.13	[0.76–1.68]	0.56
Player position	485							0.51
Forward	84	78	6	7.1		1.00		
Winger	70	65	5	7.1		1.00	[0.29–3.43]	1.00
Attacking midfielder	62	54	8	12.9		1.93	[0.63–5.87]	0.25
Central midfielder	66	61	5	7.6		1.07	[0.31–3.66]	0.92
Wingback	87	77	10	11.5		1.69	[0.59–4.87]	0.33
Center back	71	65	6	8.5		1.20	[0.37–3.90]	0.76
Goalkeeper	45	44	1	2.2		0.30	[0.03–2.53]	0.27
Level of play	508							0.89
1st division	119	109	10	8.4		1.00		
Second division	256	233	23	9.0		1.08	[0.50–2.34]	0.85
Third division	133	123	10	7.5		0.89	[0.36–2.21]	0.80
Level of play last season	485							0.71
Elite division	4	3	1	25.0		1.00		
First division	126	115	11	8.7		0.29	[0.03–3.00]	0.30
Second division	154	141	13	8.4		0.28	[0.03–2.85]	0.28
Third division or lower	201	184	17	8.5		0.28	[0.03–2.81]	0.28
Junior or senior national team matches	508							
Yes	92	86	6	6.5		0.72	[0.29–1.75]	0.46
No	416	379	37	8.9		1.00		

Comparison between the players who sustained at least one ankle injury during the following season ("Injured") and the players who did not ("Uninjured").

The number of players in the uninjured and injured groups reflect the number of players who completed each of the tests.

*Results (OR and 95% CI) are presented per increase of 1 SD.

Range (mean, minimum – maximum) of continuous variables: age (24.0, 16.2–37.7), height (181.4, 153–198), weight (77.9, 56.0–105.0), BMI (23.7, 19.4–29.8).

BMI, body mass index; OR, odds ratio; CI, confidence interval; SD, standard deviation.

Table 3. Multivariate analyses of the potential risk factors with $P<0.10$ in univariate analyses

Risk factors	Adjusted OR	95% CI	*P*-value
Previous ankle injury			
Per previous ankle injury	1.23	[1.06–1.41]	0.005
FAOS* sub-score "Pain"	0.89	[0.67–1.18]	0.41

*FAOS (foot and ankle outcome score) (Roos et al., 2001) (OR and 95% CI) are presented for a change of 10 in FAOS score.

Adjusted odds ratio (OR) and 95% confidence interval (CI) of number of previous ankle injuries as continuous variable and per difference of 10 in FAOS (foot and ankle outcome score) (Roos et al., 2001) sub-score "Pain."

whether single leg balance tests can predict the risk of new ankle injuries in male soccer (McHugh et al., 2006; Trojian & McKeag, 2006). Trojian and McKeag (2006) found a predictive value of balance tests, while McHugh et al. (2006) did not. However, several publications looking at balance, measured in different ways, as a predictor of an increased risk of injury among male athletes do exist from other sports (Tropp et al., 1984; McGuine et al., 2000; Willems et al., 2005; Wang et al., 2006; Hrysomallis et al., 2007). In the present study, none of the balance tests, on the floor or on a balance mat, turned out to be significant predictors. There are several potential explanations for this apparent discrepancy. First, even though this study is one of the largest cohort studies on risk factors for injuries to date, with as many as 56 acute ankle injuries, the statistical power is limited for multivariate tests. Nevertheless, the strength of the candidate risk factors studied does not indicate that any of these would be helpful as screening tools. As pointed out by Bahr and Holme (2003) in their review, to detect moderate to strong associations, 20–50 injury cases are needed, whereas small to moderate associations would need about 200 injured subjects. However, for a risk factor to be clinically relevant with sufficient sensitivity and specificity, strong associations are needed. Second, the results indicate that the intertester reliability for the balance tests used is low, with κ values of 0.40 and 0.19. This shows that the same player will not necessarily be scored the same way from two different tests of the same ankle, a factor that clearly influences the ability to identify players with reduced ankle control. Third, the floor test has a ceiling effect in this player population, with 97.4% of the subjects obtaining a normal or a supranormal test score. Because we suspected that this test could be too easy, we also included the balance mat test. For this, the test distribution was better (34.6%, 34.5% and 25.8% in categories 2, 3 and 4, respectively), and the main problem may be that the balance mat test is inconsistent, as indicated by the low κ value. Also, data from Australian football suggest that balance deficits do not necessarily persist among previously injured athletes (Hrysomallis et al., 2005). To identify athletes at risk based on tests measuring balance and ankle control, we clearly need to develop a new methodology with better test properties and reliability. One limitation of the current study is that we had to rely on the coaches for the exposure registration. We had no way to check their figures, but there should be no reason to misreport. If a game or a practice session was missed, it would affect all players on the team, which is unlikely to influence the analysis regarding any specific risk factor. The same should be the case for the physiotherapists registering injuries.

Using multivariate methods where we have controlled for significant risk factors as well as player exposure, this study confirms the consistent finding from previous studies that players with a history of ankle sprains are at an increased risk (Ekstrand & Gillquist, 1983; Tropp et al., 1985; Árnason et al., 2004; Kofotolis et al., 2007). The high-risk period is the first 6 months after a previous injury, as also shown in a study among volleyball players (Bahr & Bahr, 1997). It seems reasonable to recommend that injured players complete a program of balance training on a wobble board for 10 weeks, as first described by Tropp et al. (1985), and that they use tape or a brace during high-risk activities until their rehabilitation is completed (Ekstrand et al., 1983; Tropp et al., 1985). Studies have shown that taping (Ekstrand et al., 1983; Tropp et al., 1985) or using an orthotic device (Surve et al., 1994) prevents reinjury in athletes with a history of ankle sprain, but that neither of these methods appears to have any effect on athletes who have not been injured before. This may be due to the manner in which taping and braces apparently work; that is, they improve the ability of the ankle to react quickly to an inversion stress, but not as a passive mechanical support. Following these guidelines may prevent the athlete from entering a vicious circle with repeated ankle sprains and chronic ankle instability problems.

Perspectives

A history of previous acute ankle injury proved to be the only significant risk factor for new injuries to the same ankle in this prospective cohort study among male soccer players. Players with multiple and/or recent injuries are at a high risk. For practical use, the sensitivity of previous injury (yes or no) as a predictor for new ankle sprains was 74%, which means 74% of the players who sustained an ankle injury during the season had a history of ankle sprains. However, the positive predictive value was only 6%, which means that only 6% of previously injured players suffered a new ankle sprain during the season. This figure increases gradually with the number of previous injuries to 10%, if the player has had five or more previous acute ankle injuries. The same is the case if there is a history of a recent sprain, i.e. during the last 6 months (9%). Based on these results, it does not seem possible to target preventive measures based on a history of ankle sprains alone. The results from this study also show that additional information such as balance tests, player interviews or clinical examination does not increase our ability to identify players at risk.

Key words: ankle injuries, football, risk factors, prospective cohort study, previous injuries.

References

Andersen TE, Floerenes TW, Arnason A, Bahr R. Video analysis of the mechanisms for ankle injuries in football. Am J Sports Med 2004: 32: 69S–79S.

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

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

Backous DD, Friedl KE, Smith NJ, Parr TJ, Carpine WD Jr. Soccer injuries and their relation to physical maturity. Am J Dis Child 1988: 142: 839–842.

Bahr R, Bahr IA. Incidence of acute volleyball injuries: a prospective cohort study of injury mechanisms and risk factors. Scand J Med Sci Sports 1997: 7: 166–171.

Bahr R, Holme I. Risk factors for sports injuries – a methodological approach. Br J Sports Med 2003: 37: 384–392.
Bahr R, Lian O, Bahr IA. A twofold reduction in the incidence of acute ankle sprains in volleyball after the introduction of an injury prevention program: a prospective cohort study. Scand J Med Sci Sports 1997: 7: 172–177.
Baumhauer JF, Alosa DM, Renstrom AF, Trevino S, Beynnon B. A prospective study of ankle injury risk factors. Am J Sports Med 1995: 23: 564–570.
Beynnon BD, Renstrom PA, Alosa DM, Baumhauer JF, Vacek PM. Ankle ligament injury risk factors: a prospective study of college athletes. J Orthop Res 2001: 19: 213–220.
Ekstrand J, Gillquist J. Soccer injuries and their mechanisms: a prospective study. Med Sci Sports Exerc 1983: 15: 267–270.
Ekstrand J, Gillquist J, Liljedahl SO. Prevention of soccer injuries. Supervision by doctor and physiotherapist. Am J Sports Med 1983: 11: 116–120.
Ekstrand J, Tropp H. The incidence of ankle sprains in soccer. Foot Ankle 1990: 11: 41–44.
Engebretsen AH, Myklebust G, Holme I, Engebretsen L, Bahr R. Prevention of injuries among male soccer players: a prospective, randomized intervention study targeting players with previous injuries or reduced function. Am J Sports Med 2008: 36: 1052–1060.
Hägglund M, Walden M, Ekstrand J. Previous injury as a risk factor for injury in elite football: a prospective study over two consecutive seasons. Br J Sports Med 2006: 40: 767–772.
Hawkins RD, Fuller CW. A prospective epidemiological study of injuries in four English professional football clubs. Br J Sports Med 1999: 33: 196–203.
Hrysomallis C, McLaughlin P, Goodman C. Does a balance deficit persist in Australian Football players with previous lower limb ligament injury? J Sci Med Sport 2005: 8: 85–91.
Hrysomallis C, McLaughlin P, Goodman C. Balance and injury in elite Australian footballers. Int J Sports Med 2007: 28: 844–847.
Juma AH. Outline of sport injuries in the V World Youth Championship for FIFA Cup in Saudi Arabia. Ind J Med Sci 1998: 52: 433–437.
Junge A, Dvorak J, Graf-Baumann T, Peterson L. Football injuries during FIFA tournaments and the Olympic Games, 1998–2001: development and implementation of an injury-reporting system. Am J Sports Med 2004: 32: 80S–89S.
Junge A, Dvorak J, Rösch D, Graf-Baumann T, Chomiak J, Peterson L. Psychological and sport-specific characteristics of football players. Am J Sports Med 2000: 28: 22–28.
Kofotolis ND, Kellis E, Vlachopoulos SP. Ankle sprain injuries and risk factors in amateur soccer players during a 2-year period. Am J Sports Med 2007: 35: 458–466.
Lindenfeld TN, Schmitt DJ, Hendy MP, Mangine RE, Noyes FR. Incidence of injury in indoor soccer. Am J Sports Med 1994: 22: 364–371.
Lysens RJ, Ostyn MS, Vanden AY, Lefevre J, Vuylsteke M, Renson L. The accident-prone and overuse-prone profiles of the young athlete. Am J Sports Med 1989: 17: 612–619.
McGuine TA, Greene JJ, Best T, Leverson G. Balance as a predictor of ankle injuries in high school basketball players. Clin J Sport Med 2000: 10: 239–244.
McGuine TA, Keene JS. The effect of a balance training program on the risk of ankle sprains in high school athletes. Am J Sports Med 2006: 34: 1103–1111.
McHugh MP, Tyler TF, Mirabella MR, Mullaney MJ, Nicholas SJ. The effectiveness of a balance training intervention in reducing the incidence of noncontact ankle sprains in high school football players. Am J Sports Med 2007: 35: 1289–1294.
McHugh MP, Tyler TF, Tetro DT, Mullaney MJ, Nicholas SJ. Risk factors for noncontact ankle sprains in high school athletes: the role of hip strength and balance ability. Am J Sports Med 2006: 34: 464–470.
McKay GD, Goldie PA, Payne WR, Oakes BW. Ankle injuries in basketball: injury rate and risk factors. Br J Sports Med 2001: 35: 103–108.
Meeuwisse WH. Assessiong cuasation in sport injury: a multifactorial model. Clin J Sport Med 1994: 4: 166–170.
Olsen OE, Myklebust G, Engebretsen L, Holme I, Bahr R. Exercises to prevent lower limb injuries in youth sports: cluster randomised controlled trial. BMJ 2005: 330: 449–455.
Ostenberg A, Roos H. Injury risk factors in female European football. A prospective study of 123 players during one season. Scand J Med Sci Sports 2000: 10: 279–285.
Roos EM, Brandsson S, Karlsson J. Validation of the foot and ankle outcome score for ankle ligament reconstruction. Foot Ankle Int 2001: 22: 788–794.
Surve I, Schwellnus MP, Noakes T, Lombard C. A fivefold reduction in the incidence of recurrent ankle sprains in soccer players using the Sport-Stirrup orthosis. Am J Sports Med 1994: 22: 601–606.
Taerk GS. The injury-prone athlete: a psychosocial approach. J Sports Med Phys Fitness 1977: 17: 186–194.
Taimela S, Kujala UM, Osterman K. Intrinsic risk factors and athletic injuries. Sports Med 1990: 9: 205–215.
Trojian TH, McKeag DB. Single leg balance test to identify risk of ankle sprains. Br J Sports Med 2006: 40: 610–613.
Tropp H, Askling C, Gillquist J. Prevention of ankle sprains. Am J Sports Med 1985: 13: 259–262.
Tropp H, Ekstrand J, Gillquist J. Stabilometry in functional instability of the ankle and its value in predicting injury. Med Sci Sports Exerc 1984: 16: 64–66.
Tyler TF, McHugh MP, Mirabella MR, Mullaney MJ, Nicholas SJ. Risk factors for noncontact ankle sprains in high school football players: the role of previous ankle sprains and body mass index. Am J Sports Med 2006: 34: 471–475.
Wang HK, Chen CH, Shiang TY, Jan MH, Lin KH. Risk-factor analysis of high school basketball-player ankle injuries: a prospective controlled cohort study evaluating postural sway, ankle strength, and flexibility. Arch Phys Med Rehabil 2006: 87: 821–825.
Willems TM, Witvrouw E, Delbaere K, Mahieu N, De BI, De CD. Intrinsic risk factors for inversion ankle sprains in male subjects: a prospective study. Am J Sports Med 2005: 33: 415–423.

Paper III

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Intrinsic risk factors for acute knee injuries among male football players: a prospective cohort study

A. H. Engebretsen[1], G. Myklebust[1], I. Holme[1], L. Engebretsen[1,2], R. Bahr[1]

[1]Oslo Sports Trauma Research Center, Norwegian School of Sports Sciences, Oslo, Norway, [2]Department of Orthopaedic Surgery, Ulleval University Hospital, University of Oslo, Oslo, Norway

Corresponding author: A. H. Engebretsen, MD, Oslo Sports Trauma Research Center, Norwegian School of Sports Science, PO Box 4014 Ullevål Stadion, N-0806 Oslo, Norway. Tel: +47 23 26 23 57, Fax: 23 26 23 07, E-mail: anders.engebretsen@nih.no

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This prospective cohort study was conducted to identify the risk factors for acute knee injuries among male football players. A total of 508 players representing 31 amateur teams were tested during the 2004 preseason for potential risk factors for knee injury through a questionnaire on previous injury, Knee Osteoarthritis Outcome Score (KOOS) and a clinical examination. Generalized estimating equations were used in univariate analyses to identify candidate risk factors, and factors with a *P*-value <0.10 were then examined in a multivariate model. During the football season, 61 acute knee injuries, affecting 57 legs (53 players), were registered. Univariate analyses revealed the KOOS subscores "Pain" and "Function in daily living" (OR for a 10-point difference in score: 1.26, 95% CI 1.03–1.55 and 1.35, 95% CI 0.98–1.85, respectively), any findings at clinical examination (OR: 2.62, 95% CI 1.03–6.68), flexion contraction in range of motion testing (OR: 0.96, 95% CI 0.93–1.00) and varus stress tests in full extension (OR: 8.50, 95% CI 1.85–39.0) and 30° flexion (OR: 5.69, 95% CI 1.73–18.8) as candidate factors. However, in a multivariate analysis, none of these factors were associated with an increased injury risk.

Knee injuries account for 14–32% of all acute injuries (Ekstrand & Gillquist, 1983; Arnason et al., 1996; Hawkins & Fuller, 1999; Junge & Dvorak, 2004; Walden et al., 2005a, 2005b) and are the most common cause of severe injuries in male football, in many cases requiring surgical treatment. (Powell & Barber-Foss, 1999; Verrall et al., 2001; Walden et al., 2005a; Agel et al., 2007) Hence, preventing knee injuries is an important goal, and to accomplish that, the specific intrinsic risk factors must be identified. (Meeuwisse, 1994) It seems that a previous knee injury places an athlete at an increased risk of suffering a new injury to the knee, especially when rehabilitation is inadequate. (Arnason et al., 2004; Hagglund et al., 2006) Also, older players are thought to be at a higher risk than younger players. (Arnason et al., 2004) Other potential risk factors have been studied in other sports, age groups and among female athletes.

Intervention studies have shown that neuromuscular training may prevent knee sprains (Caraffa et al., 1996), indicating that reduced neuromuscular control may be an important risk factor for knee injuries. However, the evidence among adult male players is limited (Caraffa et al., 1996), as most studies have been carried out in other sports or among female or younger athletes. (Myklebust et al., 2003; Mandelbaum et al., 2005; Olsen et al., 2005).

To examine the contribution of the various risk factors and explore their interrelationship, a multivariate approach is necessary. (Meeuwisse, 1994) Even though a large number of risk factor studies have been carried out, only a few have used multivariate analyses. We therefore planned the present prospective cohort study on footballers to screen for several potential risk factors for knee injuries, some of which have not been studied in depth earlier.

One goal of this study was to investigate whether simple screening tests, which are easy to perform and do not require advanced laboratory equipment, can be used to identify individuals at risk. In this way, if the questionnaire or simple strength/sprint tests in this study were to prove useful, even teams without medical staff can test themselves in the pre-season to identify players at risk of injuries.

The aim of this study was to examine potential intrinsic risk factors for injuries to the knee in a prospective cohort study among subelite male football players. We hypothesized that a history of previous acute knee injuries, reduced function scores, abnormalities on a standard clinical examination and simple performance tests could predict an increased risk of new knee injuries. In addition, we included self-reported player information such as age, height, weight, body mass index (BMI) and player position to investigate whether there were any correlations between these variables and injury risk.

Materials and methods

Design and participants

This study is based on data from a randomized trial on male amateur football players examining the effect of a training program designed to prevent injuries. The design, the intervention program and the results of the study have been described previously in detail in a separate paper. (Engebretsen et al., 2008) Because no differences were seen in injury rates between the intervention and control groups (Engebretsen et al., 2008), the entire cohort could be used to assess the effect of a number of risk factors assessed at baseline.

A total of 35 teams ($n = 769$ players) from the Norwegian first, second or third division of football for men, geographically located in the proximity of Oslo invited to participate in the study. The third division teams either won their league or finished as first runners up the previous season, resulting in a relatively homogenous group of teams, even if they competed in three different divisions. Three of the teams ($n = 60$ players) declined the invitation to participate, 177 players did not report for testing, three players did not speak Norwegian and could therefore not complete the questionnaire and four players were excluded for other reasons (Fig. 1). Hence, 244 of the players invited could not be included. In addition, one team ($n = 17$ players) was later excluded because the physiotherapist did not record injuries, resulting in a final sample of 508 players representing 31 teams from three divisions (first division, $n = 7$, 122 players; second division, $n = 16$, 260 players; and third division, $n = 8$, 126 players). The study was approved by the Regional Committee for Medical Research Ethics, Helse Øst, and written consent was obtained.

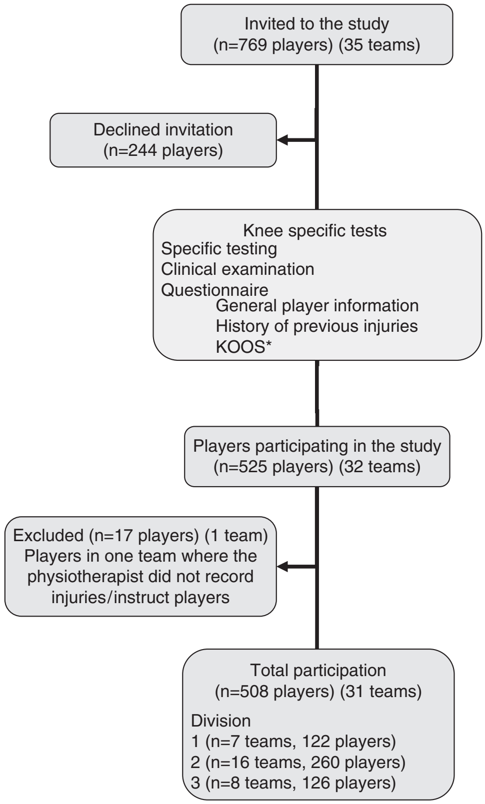

Fig. 1. Flow chart showing movement of numbers of players participating. KOOS, Knee Osteoarthritis Outcome Score.

Risk factor screening

The teams were tested for potential risk factors for knee injuries during the 2004 pre-season, January through March, at the Norwegian School of Sport Sciences. Every player capable (not injured at the time) completed three counter-movement jumps, two 40 m sprint tests, a clinical examination and a questionnaire.

The counter-movement jump test was performed on a force plate (AMTI LG6-4-1, Advanced Mechanical Technology Inc., Watertown, Massachusetts, USA), with arms held at the waist, and the player from a standing position flexed in his knees to at least 90° before he jumped as high as he could. All three tests were scored as the maximal height of rise of the center of gravity in centimeters, calculated based on data on body weight and ground reaction forces during the jump.

The 40 m sprint test was performed with a contact mat and double beam timing gates at the Norwegian School of Sport Sciences, measuring the time from when the front foot left the floor to the time sensor at 40 m.

The clinical testing of the players was performed by a group of ten sports physical therapists and sports physicians who were blinded for injury history (scars were not concealed). Both legs were examined for knee axis (normal, genu varum, genu valgum), range of motion for flexion and extension (measured in degrees), Lachman test (positive, negative), anterior drawer (positive, negative), posterior drawer (positive, negative) and valgus and varus stress tests in extension and 30° of flexion (positive, negative).

The players also completed a questionnaire in two parts, where the first part covered general player information (age, height, BMI, position on the field, number of junior or senior national team matches played, level of play this season) and history of previous injuries (number, severity, nature and number of months since the most recent knee injury, use of protective gear such as tape or brace and whether the most recent injury had caused the player to miss matches). The second part was a function score for the knee [Knee Osteoarthritis Outcome Score (KOOS)] (Roos et al., 1998) translated into Norwegian. This form consists of five major parts (symptoms, pain, function in daily living, function in sport and recreation, quality of life) and is scored by calculating the mean value of the five parts in percent of the total possible score, where 100% is the maximal and 0% is the lowest score. The KOOS form has never been used before as a screening tool as it was done in the present study.

In addition, a similar screening was performed for risk factors for ankle, hamstring and groin injuries. The data from these tests are/will be reported separately (Engebretsen et al., 2009).

Injury reporting

An injury was defined as any physical complaint sustained by a player that resulted from a football match or football training, forcing the player to miss or being unable to take full part in future football training or match play (''time-loss'' injury). Acute injuries were defined as injuries with a sudden onset associated with a known trauma, whereas overuse injuries were those with a gradual onset without any known trauma. Two of the authors were blinded to all other information regarding risk factors and categorized all injuries based on the injury reports from the physiotherapist. For the purpose of the present paper, an injury was classified as a knee injury if it was recorded as an acute injury of the knee ligaments, menisci, bone or joint cartilage, or if hemarthros had occurred as a result of knee sprain. Injuries were classified into three severity categories according to the time it took until the player was fully fit to take part in all types of organized football play: minor (1–7 days), moderate (8–28 days) and major (>28 days).

The team physiotherapist was responsible for reporting injuries for all the players on the team throughout the preseason and the season. Most of the teams from the first and second division already had a physical therapist working with the team. In cases where there was no physical therapist attached to the team, we provided them with one. However, the physiotherapist was not required to be present at every training session and match; the degree of follow-up therefore varied from team to team participating in the study. The head coach for every team registered each player's participation in training and the number of minutes played in matches.

Reliability testing

Intertest reliability tests were carried out by different test personnel for the clinical examination by having the same player repeat the same test with different personnel after he had completed the first test. Each examiner was blinded to the results of the others. The same scoring system/clinical forms were used at both stations. The intertest reliability for the categorical variables in the interpretation was computed using kappa statistics and for continuous variables as the coefficient of variation.

The intertest reliability for the clinical examination computed using κ statistics was 1.00 for all tests examined: Lachman, posterior drawer, varus stress test in extension, varus stress test in 30° of flexion, valgus stress test in extension) and valgus stress test in 30° of flexion.

Statistical methods

Exposure to matches and training was calculated by adding the individual duration of all training and match play during the season.

For the continuous dependent variable risk factor analyses, where each leg was the unit of analysis, generalized estimating equations (STATA, version 8; STATA, College station, Texas, USA) were used, accounting for total individual exposure during the football season, any within-team correlations and the fact that the left and right foot belonged to the same player. Knee injury during the season was set as the dependent variable, while total hours of football play during match and training was set as the total exposure. To account for the dependency within persons due to analyses by each leg as a unit, the correlation pattern was chosen as unstructured, i.e. without any presumption about its structure. Logistic regression analyses were used to examine the relationships between per subject calculated dichotomous injury variables and their risk factors.

All risk factor variables were examined in univariate analyses, and those with a *P*-value <0.10 were investigated further in a multivariate model. *P*-values of <0.05 were considered as statistically significant.

Results

The total incidence of injuries during the season was 4.7 injuries per 1000 playing hours (95% CI 4.3–5.1), 12.1 (95% CI 10.5–13.7) for match injuries and 2.7 (95% CI 2.4–3.1) for training injuries. The exposure to match play and training was 108 111 player hours. A total of 61 acute knee injuries were reported, affecting 57 legs and 53 (10.4%) of the 508 players in the study (Table 1). The overall incidence of acute knee injuries was 0.6 injuries per 1000 playing hours (95% CI 0.4–0.7), 0.3 injuries per 1000 training hours (95% CI 0.2–0.4) and 1.8 injuries per 1000 match hours (95% CI 1.2–2.5). A total of 46 players sustained one knee injury, six sustained two injuries and one player sustained three injuries. Of the 61 injuries, 30 occurred on the right and 31 were on the left side. There were 10 minor injuries (time loss 1–7 days), 26 moderate injuries (8–28 days) and 23 severe injuries (>28 days). In two cases, information on the duration of time loss was missing.

Univariate analyses (Table 2) revealed that the KOOS subscores ''Pain'' and ''Function in daily living'' were potential leg-dependent risk factors for acute knee injuries. Also, the clinical examination was a potential means of identifying players at risk;

Table 1. Classification of the acute knee injuries reported in the study

Classification	Number of injuries	%
Injury type		
Dislocation	2	3
Patella dislocation (MPFL tear)	2	
Meniscus tear	7	11
Medial meniscus tear	2	
Lateral meniscus tear	3	
Unspecified meniscus tear	2	
Cartilage lesion	1	2
Lateral femoral condyle	1	
Sprain	51	84
MCL	23	
LCL	4	
ACL	7	
PCL	1	
Hemarthosis	4	
Unspecified	12	
Injury severity (based on time loss)		
1–7 days	10	16
1–4 weeks	26	43
>4 weeks	23	38
Missing	2	3
Match or training injury		
Training	26	43
Match	35	57
Injured side		
Left	31	51
Right	30	49

MPFL, medial patellofemoral ligament; MCL, medial collateral ligament; LCL, lateral collateral ligament; ACL, anterior cruciate ligament; PCL, posterior cruciate ligament.

Table 2. Odds ratios for the risk of knee injury, calculated from generalized estimating equations taking into account the individual exposure and the fact that the left and the right leg belonged to the same player

	n	Current injury			OR	95% CI	*P*-value
		Uninjured ($n = 959$)	Injured ($n = 57$)				
		n/mean ± SD	*n*/mean ± SD	% injured			
Information on injury history							
Previous knee injury	1016						
Yes	352	332	20	5.7%	1.00		
No	664	627	37	5.6%	0.97	[0.55–1.71]	0.91
Number of previous injuries	1016						
No previous injury	664				1.00		
1 injury	230	220	10	4.3%	0.64	[0.31–1.30]	0.22
2 injuries	79	74	5	6.3%	1.29	[0.51–3.27]	0.60
3 injuries	25	23	2	8.0%	1.24	[0.26–5.87]	0.79
4 injuries	7	6	1	14.3%	2.75	[0.34–22.0]	0.34
5 injuries	4	4	0	0%	5.28	[1.13–24.7]	0.03
> 5 injuries	7	5	2	28.6%	9.43	[1.78–49.8]	< 0.01
Time since previous injury	1013						0.41
Never	664	627	37	5.6%	1.00		
0–6 months	86	80	6	7.0%	1.42	[0.52–3.86]	0.49
6–12 months	51	48	3	5.9%	0.99	[0.28–3.58]	0.99
1–2 years	61	57	4	6.6%	1.25	[0.40–3.87]	0.70
> 2 years	151	144	7	4.6%	0.66	[0.25–1.70]	0.39
KOOS function score*	962	95 ± 9.5	94 ± 15.1		1.14	[0.89–1.46]	0.29
Symptoms	994	93 ± 10.9	92 ± 14.3		1.12	[0.89–1.39]	0.34
Pain	1002	97 ± 8.6	94 ± 16.9		1.26	[1.03–1.55]	0.03
Function in daily living	1001	98 ± 6.4	97 ± 10.0		1.35	[0.98–1.85]	0.06
Function in sport and recreation	1004	94 ± 14.1	92 ± 20.6		1.12	[0.95–1.32]	0.16
Quality of life	1007	92 ± 14.6	90 ± 21.3		1.13	[0.96–1.32]	0.14
Clinical examination	845	795	50	5.9%			
Any pathological findings	51	45	6	11.8%	2.62	[1.03–6.68]	0.04
No pathological findings	794	750	44	5.5%	1.00		
Knee axis	877	824	53	6.0%			0.10
Normal	621	590	31	5.0%	1.00		
Genu varum	226	206	20	8.8%	1.88	[1.01–3.48]	0.05
Genu valgum	30	28	2	6.7%	1.04	[0.22–4.95]	0.96
Range of motion							
Flexion (degrees)	883	139° ± 5.9° (830)	137° ± 9.7° (53)		0.96	[0.93–1.00]	0.05
Extension (degrees)	883	0.5° ± 5.9° (830)	0.6° ± 6.4° (53)		1.03	[0.98–1.08]	0.27
Laxity tests							
Lachman test	848	798	50	5.9%			
Positive	14	13	1	7.1%	1.50	[0.17–13.0]	0.72
Negative	834	785	49	5.9%	1.00		
Anterior drawer	884	831	53	6.0%			
Positive	10	9	1	10%	2.13	[0.22–20.2]	0.51
Negative	874	52	1	0.1%	1.00		
Posterior drawer	887	834	53	6.0%			
Positive	4	4	0	0%	0.21	[0.00–775]	0.71
Negative	883	830	53	6.0%	1.00		
Valgus stress test (in extension)	885	832	53	6.0%			
Positive	9	8	1	11.1%	2.48	[0.26–23.5]	0.43
Negative	876	824	52	5.9%	1.00		
Valgus stress test (in 30° of flexion)	887	834	53	6.0%			
Positive	20	19	1	5.0%	1.00		
Negative	867	815	52	6.0%	1.13	[0.14–9.02]	0.91
Varus stress test (in extension)	887	834	50	5.6%			
Positive	9	6	3	33.3%	8.50	[1.85–39.0]	0.01
Negative	878	828	53	6.0%	1.00		
Varus stress test (in 30° of flexion)	887	834	53	6.0%			
Positive	17	13	4	23.5%	5.69	[1.73–18.8]	< 0.01
Negative	870	821	49	5.6%	1.00		

*All results (OR and 95% CI) are presented for a reduction of 10 in KOOS.

The number of legs shown for the uninjured and injured groups reflects the number for which each of the tests was completed.

Range (mean, minimum–maximum) and standard deviation (SD) of continuous variables: KOOS total score: 95.0, 17.8–100.0 (SD: 9.9); symptoms: 93.0, 10.7–100.0 (SD: 11.1); pain: 96.4, 2.8–100.0 (SD: 9.3); functions in daily living: 98.0, 36.8–100.0 (SD: 6.6); function in sport and recreation: 93.9, 0.0–100.0 (SD: 14.6); quality of Life: 92.1, 0.0–100.0 (SD: 15.1); flexion: 138.4, 105–155 (SD: 6.2); extension: -4.7, -20 -20 (SD: 5.9).

Each leg was the unit of analysis, including both continuous (mean ± SD) and categorical (yes/no) independent variables.

KOOS, Knee Osteoarthritis Outcome Score.

any positive finding at clinical examination, deviations from the normal knee axis and flexion contraction in the range of motion testing were candidate factors. As for the specific knee testing, a positive varus stress test in full extension and in 30° of flexion were potential predictors of an increased risk. However, none of the player-dependent factors tested were significantly associated with a risk of knee injury (Table 3). Because this study is based on data from a randomized trial, separate analyses controlling for group assignment (intervention or control group) were performed, but with no change in the results. Also, a Poisson model approximating multinomial logistic regression analyses was used, in order to compare players who sustained no injuries vs those who sustained one injury vs those who sustained more than one injury. Again, the results did not differ from the original analyses.

Out of a total of 1016 cases, the final multivariate analysis was based on 812 cases after cases with missing data were excluded. No significant risk factors for new acute knee injuries were identified in the final multivariate analysis (Table 4).

Discussion

The main finding of this cohort study investigating the potential risk factors for knee injuries in football was that none of the potential leg- or player-dependent risk factors studied could be used to predict increased risk of injury.

Table 4. Multivariate analysis of the potential risk factors with $P < 0.10$ in univariate analyses

Risk factors	OR	95% CI	*P*-value
KOOS			
Pain	1.15	[0.69–1.90]	0.59
Function in daily living	1.11	[0.52–2.38]	0.79
Clinical examination	2.34	[0.89–6.16]	0.09

Adjusted odds ratio (OR) and 95% confidence interval (CI) of number of previous knee injuries as continuous variable, any positive finding on clinical examination and per difference of 10 in KOOS sub scores "Pain" and "Function in daily living."

P-values are the results from analysis in STATA using generalized estimating equations.

KOOS, Knee Osteoarthritis Outcome Score.

Table 3. Odds ratios for the risk of knee injury, calculated by logistic regression analyses

Factor	*n*	Current injury: Uninjured ($n = 465$) *n*/mean ± SD	Injured ($n = 43$) *n*/mean ± SD	% injured	OR	95% CI	*P*-value
Age (years)	500	24.0 ± 4.1 (449)	24.3 ± 4.4 (51)		1.05*	[0.79–1.40]	0.75
Height (cm)	497	181.5 ± 6.1 (446)	180.4 ± 8.0 (51)		0.82*	[0.62–1.09]	0.19
Weight (kg)	493	78.1 ± 7.9 (442)	76.5 ± 8.7 (51)		0.81*	[0.60–1.09]	0.16
BMI (kg/m^2)	486	23.7 ± 1.7 (437)	23.6 ± 1.4 (49)		0.94*	[0.69–1.27]	0.42
Player position	485	435	50	10.3%			0.63
Forward	84	77	7	8.3%	1.00		
Winger	70	62	8	11.4%	1.45	[0.50–4.23]	0.50
Attacking midfielder	62	58	4	6.5%	0.79	[0.22–2.82]	0.71
Central midfielder	66	58	8	12.1%	1.54	[0.53–4.50]	0.43
Wingback	87	73	14	16.1%	2.18	[0.83–5.73]	0.11
Center back	71	68	3	4.2%	1.70	[0.54–5.42]	0.31
Goalkeeper	45	39	6	13.3%	1.70	[0.54–5.42]	0.37
Level of play	508	455	53	10.4%			0.14
1st division	119	102	17	14.3%	1.00		
2nd division	256	229	27	10.5%	0.76	[0.36–1.59]	0.46
3rd division	133	124	9	6.8%	0.48	[0.18–1.28]	0.14
Junior or senior national team matches	508	455	53	10.4%			
Yes	92	85	7	7.6%	0.68	[0.30–1.56]	0.36
No	416	370	46	11.1%	1.00		
Knee function testing (best results)							
Counter movement jump test	423	38.6 ± 4.7 (381)	38.2 ± 4.6 (42)		1.13*	[0.83–1.55]	0.44
40-m sprint test	398	5.20 ± 0.2 (363)	5.18 ± 0.2 (35)		0.94*	[0.64–1.38]	0.74

*Per increase of one standard deviation.

The number of players in the uninjured and injured groups reflects the number of players who completed each of the tests.

Range (mean, minimum–maximum) and standard deviation (SD) of continuous variables: age: 24.0, 16.2–37.7 (SD: 4.2); height: 181.4, 153–198 (SD: 6.3); weight: 77.9, 56–105 (SD: 8.0); BMI: 23.7, 19.4–29.8 (SD: 1.7); counter movement jump test: 37.7, 25.9–56.8 (SD: 4.7), 40 m sprint test: 5.20, 4.71–5.81 (SD: 0.2).

Each player was the unit of analysis, including both continuous (mean ± SD) and categorical (yes/no) independent variables.

BMI, body mass index.

The literature on risk factors for acute knee injuries among male football players is limited. Previous knee injuries seem to be the most important risk factor for new injuries, both in male football (Ekstrand & Gillquist, 1983; Arnason et al., 2004; Hagglund et al., 2006) and among male athletes in other sports. (Meeuwisse et al., 2003; Taunton et al., 2003; Yung et al., 2007) Arnason et al. (2004) found previous knee injury to be the only significant risk factor for a new injury to the same knee in a large cohort study investigating risk factors for football injuries. In the same study, increased valgus laxity was associated with a history of previous injury. In a recent study among female youth football players, previous injury was the only risk factor identified. (Steffen et al., 2008a) These results are in contrast to the present study, where no association was seen between previous injury and new injuries in the categorical analysis. However, there is a trend suggesting an association between injury risk and the number of self-reported previous knee injuries. Also, as we observed a highly significant correlation between any pathological finding on the clinical knee examination and increased injury risk, this represents indirect evidence of the same association. It could be that the most serious injuries, causing abnormalities that could be detected through the clinical exam, do predispose a player toward new injuries. In this study, the sensitivity and specificity were 36% and 99% for the Lachman test with respect to identifying players with self-reported previous ACL injuries. Still, the overall findings in this study indicate that the strength of the candidate risk factor of previous injury is low and alone it cannot be used to identify and target high risk players with preventive measures, at least not in this player population.

Although one should think that significant injuries should be easily remembered, there are indications in the literature that the number of previous injuries or even injury location may be difficult to report correctly. (Gabbe et al., 2003) Therefore, recall bias may be a significant factor. (Arnason et al., 2004; Steffen et al., 2008a) Nevertheless, a recent study from Swedish elite football bypassed this problem by including prospective data collected over two consecutive seasons. They showed that an injury in the first season increased injury risk during the subsequent season. (Hagglund et al., 2006).

Of the other potential risk factors suggested from studies in different sports, age groups or among female athletes in the literature (gender, (Lindenfeld et al., 1994; Ahmad et al., 2006; McLean et al., 2007) age, (Backous et al., 1988; Lindenfeld et al., 1994; Ostenberg & Roos, 2000) slow reaction time, (Taimela et al., 1990) personality factors, (Taerk, 1977; Lysens et al., 1989; Taimela et al., 1990; Junge et al., 2000) disobeying fair play, (Roberts et al., 1996; Peterson et al., 2000) playing position, (Lindenfeld et al., 1994) quadriceps-to-hamstring strength ratio, (Ahmad et al., 2006) landing technique, (Hass et al., 2005; McLean et al., 2007) fatigue, (McLean et al., 2007) neuromuscular control of the knee (Hewett et al., 2005) or trunk (Zazulak et al., 2007), a history of low back pain (Zazulak et al., 2007) and general joint laxity (Baumhauer et al., 1995; Ostenberg & Roos, 2000; Beynnon et al., 2001; Myer et al., 2008), only age was tested in this study and this did not prove useful. It should be noted that knee joint laxity was tested through static stress tests; this should not be confused with the dynamic valgus pattern associated with non-contact ACL injuries among female athletes.(Hewett et al., 2005) We also included maximal jump and sprint test in this study because we hypothesized that players generating the largest forces when running and cutting and in landings could be at a greater risk of knee injury. Moreover, in the present study, different self-reported measures of body size (height, weight, BMI) were not associated with an increased injury risk, which is in accordance with previous risk factor studies. (Arnason et al., 2004; Steffen et al., 2008b).

Elite players only constitute a small portion of all football players, and advanced resources for screening tests are not available for the majority of players. Therefore, the main purpose of the current study was to see whether simple tests could be used to screen for injury risk. More advanced tests requiring advanced laboratory equipment have been used in studies on risk factors for ACL injuries among female athletes, (Hewett et al., 2005; Ahmad et al., 2006; Zazulak et al., 2007) and an association has been demonstrated with deficits in neuromuscular control of the trunk, biomechanical measures of neuromuscular control and valgus loading of the knee, and a high quadriceps-to-hamstring ratio.

Limitations

While most of the teams in the first and second division already had a physical therapist working with the team, we had to provide the remaining teams with one to be responsible for the injury reporting. They were rewarded with a stipend, but the resources were not sufficient to allow for daily follow-up of the teams by the physical therapist. Thus, there is a potential bias in injury reporting depending on the availability of the physical therapist, at least for minor injuries. This could also partly explain the low injury rate in this study compared with other studies in football, even though most of these studies are from the elite level, where the injury rate is expected to be higher. (Ekstrand & Gillquist, 1983; Arnason et al., 1996; Hawkins & Fuller, 1999; Junge & Dvorak, 2004; Walden et al., 2005a, 2005b).

Also, in the current study, we had to rely on the coaches for the exposure registration. We had no way to check their figures, but there should be no reason to misreport. If a game or a practice session was missed, it would affect all players on the team, which is unlikely to influence the analysis regarding any specific risk factor. The same should be the case for the physiotherapists registering injuries.

This study is one of the largest cohort studies on risk factors for injuries to date, with as many as 61 acute knee injuries. Nevertheless, the statistical power is limited for multivariate tests. Still, the strength of the candidate risk factors studied does not indicate that any of these would be helpful as screening tools. As pointed out by Bahr and Holme (2003) in their review, to detect moderate to strong associations, 20–50 injury cases are needed, whereas small to moderate associations would need about 200 injured subjects. However, for a risk factor to be clinically relevant with sufficient sensitivity and specificity, strong associations are needed. The objective of risk factor research is to identify clinically relevant, not just statistically significant factors. In this context, several of the factors that were found to be statistically significant in the univariate analysis are unlikely to be clinically relevant. Our conclusions are therefore based solely on the results of the final multivariate analysis.

This study was carried out among subelite male football players, and should not be extrapolated to other sports, females, youth players or other levels of play.

Perspectives

Because elite players only constitute a small portion of all football players, and advanced resources for screening tests are not available for the majority of players, the main goal of this study was to see whether players at a high risk of sustaining acute knee injuries could be identified through simple screening tests such as questionnaires or through a pre-participation physical examination by a physician or a physical therapist. We therefore did not include tests requiring advanced laboratory equipment in the study. Based on the present results, it does not seem possible to screen players in the pre-season with the tools used in this study, at least not in this player population. Whether more advanced testing would make it possible to identify players at a risk of acute knee injuries in male football is not known.

Key words: knee injuries, football, risk factors, prospective cohort study, previous injuries.

References

Agel J, Evans TA, Dick R, Putukian M, Marshall SW. Descriptive epidemiology of collegiate men's soccer injuries: National Collegiate Athletic Association Injury Surveillance System, 1988–1989 through 2002–2003. J Athl Train 2007: 42: 270–277.

Ahmad CS, Clark AM, Heilmann N, Schoeb JS, Gardner TR, Levine WN. Effect of gender and maturity on quadriceps-to-hamstring strength ratio and anterior cruciate ligament laxity. Am J Sports Med 2006: 34: 370–374.

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

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

Backous DD, Friedl KE, Smith NJ, Parr TJ, Carpine WD. Jr. Soccer injuries and their relation to physical maturity. Am J Dis Child 1988: 142: 839–842.

Bahr R, Holme I. Risk factors for sports injuries – a methodological approach. Br J Sports Med 2003: 37: 384–392.

Baumhauer JF, Alosa DM, Renstrom AF, Trevino S, Beynnon B. A prospective study of ankle injury risk factors. Am J Sports Med 1995: 23: 564–570.

Beynnon BA, Renstrom PA, Alosa DM, Baumhauer JF, Vacek PM. Ankle ligament injury risk factors: a prospective study of college athletes. J Orthop Res 2001: 19: 213–220.

Caraffa A, Cerulli G, Projetti M, Aisa G, Rizzo A. Prevention of anterior cruciate ligament injuries in soccer. A prospective controlled study of proprioceptive training. Knee Surg Sports Traumatol Arthrosc 1996: 4: 19–21.

Ekstrand J, Gillquist J. Soccer injuries and their mechanisms: a prospective study. Med Sci Sports Exerc 1983: 15: 267–270.

Engebretsen AH, Myklebust G, Holme I, Engebretsen L, Bahr R. Prevention of injuries among male soccer players: a prospective, randomized intervention study targeting players with previous injuries or reduced function. Am J Sports Med 2008: 36: 1052–1060.

Engebretsen AH, Myklebust G, Holme I, Engebretsen L, Bahr R. Intrinsic risk factors for acute ankle injuries among male soccer players: a prospective cohort study. Scand J Med Sci Sports 2009. [Epub ahead of print].

Gabbe BJ, Finch CF, Bennell KL, Wajswelner H. How valid is a self reported 12 month sports injury history? Br J Sports Med 2003: 37: 545–547.

Hagglund M, Walden M, Ekstrand J. Previous injury as a risk factor for injury in elite football: a prospective study over two consecutive seasons. Br J Sports Med 2006: 40: 767–772.

Hass CJ, Schick EA, Tillman MD, Chow JW, Brunt D, Cauraugh JH. Knee biomechanics during landings: comparison of pre- and postpubescent females. Med Sci Sports Exerc 2005: 37: 100–107.

Hawkins RD, Fuller CW. A prospective epidemiological study of injuries in four English professional football clubs. Br J Sports Med 1999: 33: 196–203.

Hewett TE, Myer GD, Ford KR, Heidt RS Jr., Colosimo AJ, McLean SG, van den Bogert AJ, Paterno MV, Succop P. Biomechanical measures of neuromuscular control and valgus loading of the knee predict anterior cruciate ligament injury risk in female athletes: a prospective study. Am J Sports Med 2005: 33: 492–501.
Junge A, Dvorak J. Soccer injuries: a review on incidence and prevention. Sports Med 2004: 34: 929–938.
Junge A, Dvorak J, Rösch D, Graf-Baumann T, Chomiak J, Peterson L. Psychological and sport-specific characteristics of football players. Am J Sports Med 2000: 28: 22–28.
Lindenfeld TN, Schmitt DJ, Hendy MP, Mangine RE, Noyes FR. Incidence of injury in indoor soccer. Am J Sports Med 1994: 22: 364–371.
Lysens RJ, Ostyn MS, Vanden AY, Lefevre J, Vuylsteke M, Renson L. The accident-prone and overuse-prone profiles of the young athlete. Am J Sports Med 1989: 17: 612–619.
Mandelbaum BR, Silvers HJ, Watanabe DS, Knarr JF, Thomas SD, Griffin LY, Kirkendall DT, Garrett W. Jr. Effectiveness of a neuromuscular and proprioceptive training program in preventing anterior cruciate ligament injuries in female athletes: 2-year follow-up. Am J Sports Med 2005: 33: 1003–1010.
McLean SG, Fellin RE, Suedekum N, Calabrese G, Passerallo A, Joy S. Impact of fatigue on gender-based high-risk landing strategies. Med Sci Sports Exerc 2007: 39: 502–514.
Meeuwisse WH. Assessing causation in sport injury: a multifactorial model. Clin J Sport Med 1994: 4: 166–170.
Meeuwisse WH, Sellmer R, Hagel BE. Rates and risks of injury during intercollegiate basketball. Am J Sports Med 2003: 31: 379–385.
Myer GD, Ford KR, Paterno MV, Nick TG, Hewett TE. The effects of generalized joint laxity on risk of anterior cruciate ligament injury in young female athletes. Am J Sports Med 2008: 36: 1073–1080.
Myklebust G, Engebretsen L, Braekken IH, Skjolberg A, Olsen OE, Bahr R. Prevention of anterior cruciate ligament injuries in female team handball players: a prospective intervention study over three seasons. Clin J Sport Med 2003: 13: 71–78.
Olsen OE, Myklebust G, Engebretsen L, Holme I, Bahr R. Exercises to prevent lower limb injuries in youth sports: cluster randomised controlled trial. BMJ 2005: 330: 449–455.
Ostenberg A, Roos H. Injury risk factors in female European football. A prospective study of 123 players during one season. Scand J Med Sci Sports 2000: 10: 279–285.
Peterson L, Junge A, Chomiak J, Graf-Baumann T, Dvorak J. Incidence of football injuries and complaints in different age groups and skill-level groups. Am J Sports Med 2000: 28: S51–S57.
Powell JW, Barber-Foss KD. Injury patterns in selected high school sports: a review of the 1995–1997 seasons. J Athl Train 1999: 34: 277–284.
Roberts WO, Brust JD, Leonard B, Hebert BJ. Fair-play rules and injury reduction in ice hockey. Arch Pediatr Adolesc Med 1996: 150: 140–145.
Roos EM, Roos HP, Lohmander LS, Ekdahl C, Beynnon BD. Knee Injury and Osteoarthritis Outcome Score (KOOS) – development of a self-administered outcome measure. J Orthop Sports Phys Ther 1998: 28: 88–96.
Steffen K, Myklebust G, Andersen TE, Holme I, Bahr R. Self-reported injury history and lower limb function as risk factors for injuries in female youth soccer. Am J Sports Med 2008a: 36: 700–708.
Steffen K, Pensgaard AM, Bahr R. Self-reported psychological characteristics as risk factors for injuries in female youth football. Scand J Med Sci Sports 2008b: 3(10): 442–451.
Taerk GS. The injury-prone athlete: a psychosocial approach. J Sports Med Phys Fitness 1977: 17: 186–194.
Taimela S, Kujala UM, Osterman K. Intrinsic risk factors and athletic injuries. Sports Med 1990: 9: 205–215.
Taunton JE, Ryan MB, Clement DB, McKenzie DC, Lloyd-Smith DR, Zumbo BD. A prospective study of running injuries: the Vancouver Sun Run "In Training" clinics. Br J Sports Med 2003: 37: 239–244.
Verrall GM, Slavotinek JP, Barnes PG, Fon GT, Spriggins AJ. Clinical risk factors for hamstring muscle strain injury: a prospective study with correlation of injury by magnetic resonance imaging. Br J Sports Med 2001: 35: 435–439.
Walden M, Hagglund M, Ekstrand J. Injuries in Swedish elite football – a prospective study on injury definitions, risk for injury and injury pattern during 2001. Scand J Med Sci Sports 2005a: 15: 118–125.
Walden M, Hagglund M, Ekstrand J. UEFA champions league study: a prospective study of injuries in professional football during the 2001–2002 season. Br J Sports Med 2005b: 39: 542–546.
Yung PS, Chan RH, Wong FC, Cheuk PW, Fong DT. Epidemiology of injuries in Hong Kong elite badminton athletes. Res Sports Med 2007: 15: 133–146.
Zazulak BT, Hewett TE, Reeves NP, Goldberg B, Cholewicki J. Deficits in neuromuscular control of the trunk predict knee injury risk: a prospective biomechanical-epidemiologic study. Am J Sports Med 2007: 35: 1123–1130.

Paper IV

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Intrinsic Risk Factors for Hamstring Injuries Among Male Soccer Players

A Prospective Cohort Study

Anders Hauge Engebretsen,*† MD, Grethe Myklebust,† PT, PhD, Ingar Holme,† PhD,
Lars Engebretsen,†‡ MD, PhD, and Roald Bahr,† MD, PhD
From the †Oslo Sports Trauma Research Center, Norwegian School of Sports Sciences, Oslo, Norway, and the ‡Department of Orthopaedic Surgery, Ulleval University Hospital, University of Oslo, Oslo, Norway

Background: Strain injuries of the posterior thigh are common in soccer. It seems that previous injury and age are important risk factors, but the literature is limited. This study was conducted to see if we could identify intrinsic risk factors for hamstring injuries among male soccer players.

Hypothesis: We hypothesized that previous hamstring injuries, reduced function scores, abnormalities on a clinical examination, high maximum sprint speed, poor hamstring strength, or low hamstring/quadriceps ratio can predict increased risk of new hamstring injuries.

Study Design: Cohort study; Level of evidence, 2.

Methods: A total of 508 players representing 31 amateur teams were tested during the 2004 preseason for potential risk factors for hamstring injury through a questionnaire on previous injury and function score (Hamstring Outcome Score [HaOS]), a clinical examination of the hamstring, and specific hamstring relevant tests. Generalized estimating equations were used in univariate analyses to identify candidate risk factors, and factors with a P value of $<.10$ were then examined in a multivariate model.

Results: During the soccer season, 76 hamstring injuries, affecting 65 legs (61 players), were registered. Univariate analyses revealed previous acute hamstring injury (yes/no) (odds ratio [OR], 2.62; 95% confidence interval [CI], 1.54-4.45), HaOS function score with all subscores except ''Soreness'' (OR for a 10-point difference in total score, 1.29; 95% CI, 1.08-1.54), age (OR, 1.25; 95% CI, 0.96-1.63), and player position ($P = .09$) as candidate predictors of high injury risk. In a multivariate analysis, the most important risk factor for injuries to the hamstring was previous acute hamstring injury (yes/no) (adjusted OR, 2.19; 95% CI, 1.19-4.03; $P = .01$).

Conclusion: In a multivariate analysis, previous acute hamstring injury was found to be a significant risk factor for new hamstring injuries. Previously injured players have more than twice as high a risk of sustaining a new hamstring injury.

Keywords: hamstring injuries; soccer; risk factors; prospective cohort study; previous injuries

Strain injuries of the posterior thigh are among the most common injuries in soccer and account for 10% to 23% of all acute injuries.[2,10,18,21,22,29,30] Also, a vicious circle with recurrent hamstring injuries is not uncommon, resulting in a chronic problem with significant morbidity in terms of symptoms, reduced performance, and time loss from sports. Hence, prevention of the first as well as repeated hamstring injuries is important.

To prevent new injuries, the specific intrinsic and extrinsic risk factors for hamstring injury in soccer players must be identified.[24] Regarding intrinsic risk factors, it seems that previous hamstring injury, especially when rehabilitation is inadequate, places an athlete at increased risk of suffering an injury to the hamstring.[3] Also, age has been shown to be a risk factor, independent of previous injury.[3] The same risk factors have been identified in other sports as well.[14]

Although studies examining whether low hamstring strength is a significant risk factor have produced conflicting results, a recent intervention study has shown

*Address correspondence to Anders Hauge Engebretsen, MD, Oslo Sports Trauma Research Center, Norwegian School of Sports Sciences, PO Box 4014 Ullevål Stadion, N-0806 Oslo, Norway (e-mail: Anders.Engebretsen@nih.no).

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a preventive effect of the specific eccentric strength exercise "Nordic hamstring lowers."[1] In a pilot study, another eccentric exercise was also shown to be useful.[4]

A multivariate approach should be used to examine the contribution of various risk factors for injuries and explore their interrelationship.[24] Among male soccer players, there are few risk factor studies that have included multivariate analyses. We therefore planned the present prospective cohort study on soccer players to screen for several potential risk factors for hamstring injuries, some of which have not been studied in depth earlier.

Elite players constitute only a small portion of all soccer players, and advanced resources for screening tests are not available for the majority of players. Therefore, one goal of this study was to investigate if simple screening tests, which are easy to do and do not require advanced equipment, can be used to identify individuals at risk. In this way, if the questionnaire and simple strength and sprint tests in this study prove useful, teams and players with minimal resources can test themselves in the preseason to find out whether they have an increased risk of injuries.

We hypothesized that previous acute hamstring injuries, reduced function scores, abnormalities on a clinical examination, high maximum sprint speed, short hamstring muscles, poor hamstring strength, or a low hamstring/quadriceps strength ratio can predict increased risk of new hamstring injuries. In addition, we included player information such as age, height, weight, body mass index (BMI), and player position to investigate if there were any correlations between these variables and injury risk. Hence, the aim of this study was to examine potential intrinsic risk factors for injuries to the hamstrings in a prospective cohort study among subelite male soccer players.

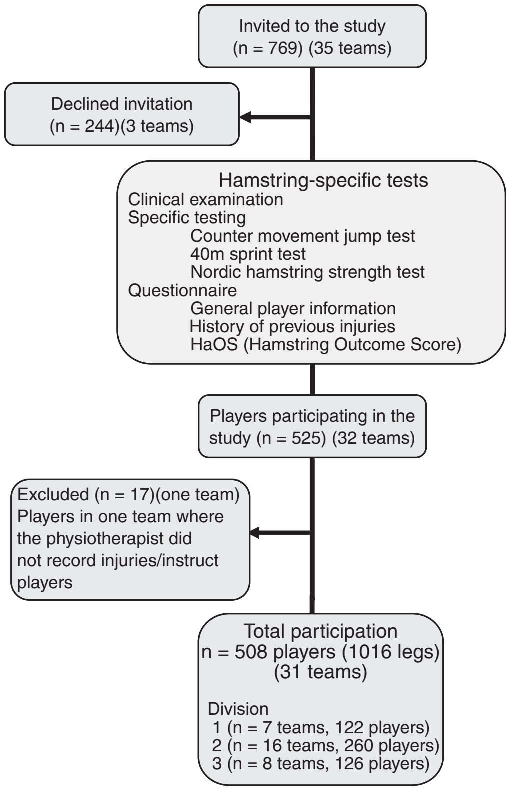

Figure 1. Flow chart showing movement of numbers of players participating.

MATERIALS AND METHODS

Design and Participants

This study is based on data from a randomized trial on male amateur soccer players examining the effect of a training program designed to prevent injuries. The design, the intervention program, and the results of the study have previously been described in detail in a separate paper.[12] Because no differences were seen in injury rates between the intervention and control groups,[12] the entire cohort could be used to examine the effect of a number of risk factors assessed at baseline.

A total of 35 teams (n = 769 players) from the Norwegian 1st, 2nd, or 3rd division of soccer for men, geographically located in the proximity of Oslo, were invited to participate in the study. In Norway, there are several different 3rd division conferences, and the 3rd division teams included either won their conference or finished as first runners up the previous season, resulting in a relatively homogeneous group of teams, even if the 35 teams competed in 3 different divisions. Three of the teams (n = 60 players) declined the invitation to participate, 177 players did not report for testing, 3 players did not speak Norwegian and could therefore not complete the questionnaire, and 4 players were excluded for other reasons (Figure 1). Hence, 244 of the players invited could not be included. In addition, 1 team (n = 17 players) was later excluded because the physiotherapist did not record injuries, resulting in a final sample of 508 players representing 31 teams from 3 divisions (1st division, n = 7, 122 players; 2nd division, n = 16, 260 players; and 3rd division, n = 8, 126 players).

Risk Factor Screening

The teams were tested for potential risk factors for hamstring injuries during the 2004 preseason, January through March, at the Norwegian School of Sport Sciences. Every player capable (not injured at the time) completed 3 countermovement jumps, two 40-m sprint tests, a Nordic hamstring strength test, a clinical examination including hamstring length measurement, and a questionnaire.

The countermovement jump test was performed on a force plate, with hands held at the hips as described by Lian et al.[23] From a standing position with straight knees,

Figure 2. The Nordic hamstring strength test. The player was instructed to lower his upper body toward the floor in a slow and controlled manner, always keeping his back and hips straight. The test was scored in 2 categories (weak or strong) according to whether the player could hold the position beyond 30° or not.

the player squatted down to at least 90° of knee flexion before jumping as high as he could. All 3 tests were scored as the maximal height of rise of the center of gravity in centimeters, calculated based on data on body weight and ground-reaction forces on the force plate during the jump. The best result was used for the analysis.

The 40-m sprint test was performed with time cells at the Norwegian Olympic Training Center, measuring the time from when the front foot left the floor to the time sensor at 40 m.

The Nordic hamstring strength test was developed for this study based on the Nordic hamstring exercise.[1,25] The player was instructed to lower his upper body toward the floor in a slow and controlled manner, always keeping his back and hips straight, until the point where he had to let go with his hamstrings, thereby falling toward the ground (Figure 2). The test was done twice; the best result was used and scored in 2 categories according to whether the player could hold the position beyond 30° of forward flexion (strong) or not (weak). The choice of 30° as a cut-off point was arbitrary, as this test has never before been used for screening. However, based on results from a pilot study, 30° was believed to be a relevant cut-off point to separate players with reasonably strong hamstrings from weaker players.

The clinical testing of the players was performed by a group of 10 sports physical therapists and sports physicians who were blinded to injury history. The players were examined for hip range of motion and determined to be tender on palpation of the hamstrings, iliopsoas, and psoas major muscles (yes/no). In addition, hamstring length was measured in degrees using the passive knee extension test, as described in detail by Árnason et al.[3]

The players also completed a questionnaire in 2 parts, where the first part covered general player information (age, height, BMI, position on the field, number of junior or senior national team matches played, level of play this season, and level of play the previous season) and previous injuries (number, severity, nature, and number of months since the most recent hamstring injury, and if the most recent injury had caused the player to miss matches). The second part was a function score for the hamstrings (Hamstring Outcome Score [HaOS]), which was developed as a screening tool.[12] This form has a similar outline as the Knee Injury and Osteoarthritis Outcome Score (KOOS) form,[27] which consists of 5 major parts (symptoms and stiffness, pain, function in daily living, function in sports and recreational activities, and quality of life) and is scored by calculating the mean value of the 5 parts in percentage of the total possible score, where 100% is the maximal and 0% the lowest score. For the HaOS score, we replaced the category "function in daily living" with a category on muscle soreness, resulting in 5 categories (symptoms, pain, soreness, function in sports, and quality of life).

In addition, a similar screening was done for risk factors for ankle, knee, and groin injuries. The data from these tests are reported in separate papers.

Injury Reporting

An injury was defined as any physical complaint sustained by a player that made him seek medical assistance and that resulted from a soccer match or soccer training, forcing him to miss or being unable to take full part in future soccer training or match play ("time-loss" injury). Acute injuries were defined as injuries with a sudden onset associated with a known trauma, whereas overuse injuries were those with a gradual onset without any known trauma. Two of the authors were blinded to all other information regarding risk factors and categorized all injuries based on the injury reports from the physiotherapist. For the purpose of the present article, an injury was classified as a hamstring strain if it was recorded as either an acute or an overuse muscle injury of the posterior thigh. Injuries were classified into 3 severity categories according to the time it took until the player was fully fit to take part in all types of organized soccer play: minor (1-7 days), moderate (8-28 days), and major (>28 days). Overuse injuries in which there was no time loss were included to incorporate small repeated strain injuries, as some players still elect to play despite discomfort in the posterior thigh. The head coach for every team registered each player's participation in training and the number of minutes played in matches.

The team physical therapist was responsible for reporting injuries on their team throughout the preseason and the season. Most of the teams from the 1st and 2nd division already had a physical therapist working with the team. In case there was no physical therapist involved, we assigned one for the team. However, the physical therapist was not required to be present at every training session and match; the degree of follow-up therefore varied from team to team participating in the study.

Reliability Testing

Intertest reliability tests were carried out for both the clinical examination of hamstring muscle length and the

Nordic hamstring strength test by having the same player repeat the same test with different personnel after he had completed the first test. Each examiner was blinded to the other's results. The same scoring system/clinical forms were used at both stations. Intertest reliability for the categorical variables in the interpretation of the Nordic hamstring strength tests was computed using κ statistics, while the coefficient of variation for the continuous variable hamstring muscle length was calculated as the standard deviation of the difference between the first and second test as a percentage of the average test results for both tests.

Statistical Methods

Exposure to matches and training was calculated by adding the individual duration of all training and match play during the season. For the continuous dependent variable risk factor analyses, in which each leg was the unit of analysis, generalized estimating equations (STATA version 8, College Station, Texas) were used, accounting for individual exposure during the soccer season, any within-team correlations, and the fact that the left and the right leg belonged to the same player. Logistic regression analyses were used to analyze the relationships between per subject calculated dichotomous injury variables and their risk factors. All risk factor variables were examined in univariate analyses, and those with a P value <.10 were investigated further in a multivariate model.

RESULTS

A total of 505 injuries were reported, sustained by 283 (56%) of the 508 players included in the study. The total incidence of injuries during the season was 4.7 injuries per 1000 playing hours (95% CI, 4.3-5.1): 12.1 (227 injuries) (95% CI, 10.5-13.7) for match injuries and 2.7 (243 injuries) (95% CI, 2.4-3.1) for training injuries (in 35 cases, it was not reported whether the injury occurred during a match or training). The total exposure to match play (19 008 hours) and training (89 103 hours) was 108 111 player hours. A total of 76 hamstring injuries were reported, affecting 65 legs and 61 (12.0%) of the 508 players in the study. Of these, there were 51 acute and 25 overuse injuries. The total incidence of hamstring injuries was 0.7 injuries per 1000 playing hours (95% CI, 0.5-0.9), 0.3 injuries per 1000 training hours (95% CI, 0.2-0.4), and 1.8 injuries per 1000 match hours (95% CI, 1.2-2.5). A total of 48 players sustained 1 hamstring injury, 11 sustained 2 injuries, and 2 players sustained 3 injuries. Of the 76 injuries, 40 occurred on the right side, and 36 were on the left side. There were 25 minor injuries (time loss, 1-7 days), 31 moderate injuries (8-28 days), and 10 severe injuries (>28 days), while information on the duration of time loss was missing in 5 cases. In 5 overuse injuries, there was no time loss.

Intertest reliability computed using κ statistics was .24 for the Nordic hamstring strength test. The coefficient of variation for the continuous variable hamstring muscle length was 9.1%.

TABLE 1
Multivariate Analysis of Candidate Risk Factors (With $P < .10$ in Univariate Analyses)[a]

Risk Factors	Adjusted OR	95% CI	*P* Value
Player-dependent factors			
Age	1.05[b]	0.77-1.42	.77
Player position	0.96	0.82-1.12	.61
Leg-dependent factors			
Previous acute hamstring injury (yes/no)	2.19	1.19-4.03	.01
HaOS total score	1.16[c]	0.95-1.42	.14

[a]Adjusted odds ratio (OR) and 95% confidence interval (CI) of age, player position (central midfielder or not), previous hamstring injury (yes/no), and Hamstring Outcome Score (HaOS) total score. *P* values are the results from analysis in STATA using generalized estimating equations.

[b]OR and 95% CI are presented for a change of 1 standard deviation, 4.2 years.

[c]OR and 95% CI are presented for a reduction of 10 in HaOS.

Univariate analyses revealed previous acute hamstring injury (yes/no), total HaOS function score, and 4 of 5 subscores of symptoms, pain, function in sports, and quality of life as potential leg-dependent risk factors for hamstring injuries (see Appendix 1, available in the online version of this article at http://ajs.sagepub.com/supplemental/). Of the player-dependent factors, age and player position were identified as potential predictors of increased injury risk (see Appendix 2, available in the online version of this article at http://ajs.sagepub.com/supplemental/). Because this study is based on data from a randomized trial, separate analyses controlling for group assignment (intervention or control group) were performed, however, with no change in the results. Also, a Poisson model approximating multinomial logistic regression analyses was used to compare players who sustained no injuries versus those who sustained 1 injury versus those who sustained more than 1 injury. Again, the results did not differ from the original analyses.

Risk factors with a P value of <.10 were then considered as candidates to predict which players are more prone to sustain an injury to the hamstring. Because these factors may be intercorrelated or confounded by each other, a multivariate analysis was performed, and previous acute hamstring injury was found to be a significant risk factor for new hamstring injuries (adjusted OR, 2.19 [1.19-4.03], $P = .01$) (Table 1). Of a total of 1016 cases, the final multivariate analysis was based on 893 cases after cases with missing data were excluded.

DISCUSSION

The main finding of this cohort study investigating potential risk factors for hamstring injuries in soccer was that a previous acute hamstring injury is a significant risk factor. Previously injured players have more than twice as high a risk of sustaining a new hamstring injury. Other candidates for identification of players with increased risk of hamstring injuries were age, player position, and hamstring function score. However, none of these proved significant in the multivariate analysis. Among other potential predictors of increased risk such as clinical examination, hamstring muscle length measurement, countermovement jump test, Nordic hamstring strength test, 40-m sprint test, level of play, or other player characteristics, none were associated with increased risk in this study.

Several authors have found previous acute hamstring strains to be a significant risk factor for new injuries, both in male soccer[3,16] and among male athletes in other sports.[14,15] This is in accordance with the present findings, showing that the injury risk is doubled among previously injured players. Although the results were not significant, the risk seems to increase gradually with the number of previous injuries and decrease with time since the previous injury.

The rationale for the high rate of recurrent strain injuries is not fully known but may be the result of scar tissue formation or other structural changes[20,26] or that full function has not been restored. In that case, the results serve to underline the importance of adequate rehabilitation before return to full participation. Also, the increased risk associated with a previous injury implicates that preventing the first injury should be a high priority to keep players from entering the vicious cycle of repeated injuries to the same body part. The Nordic hamstring exercise is the best documented preventive exercise for hamstring injuries[1,4] and has been shown to increase muscle strength and does not require advanced equipment.[25] It therefore seems reasonable to suggest that all soccer players, especially players with a history of hamstring injury, use this exercise regularly.[1,4] Because the compliance with preventive exercises is low,[12] we recommend that they are done during team practices under supervision.

Strength deficits or imbalances have been suggested to increase hamstring injury risk,[8] although the relationship between advanced isokinetic testing and injury risk is not fully resolved.[7] Isokinetic tests have been criticized for their lack of specificity, and the fact that eccentric strength training can prevent strains made us hypothesize that the Nordic hamstring exercise could be used as a simple screening test to identify players at risk. However, there was no association between the test and injury risk. The most likely explanation for this is that the reliability for the Nordic hamstring strength test is low, with a κ value of only .24. This shows that the same player will not necessarily be scored the same way on 2 separate tests, a factor that clearly influences the ability to identify players with poor hamstring strength. It could also be that the cut-off angle was set too high or low. Another factor may be that the test examines the combined strength of both sides, which means that side-to-side imbalances or weakness related to previous injury on one side therefore will be difficult to detect.

In addition to previous injury, Árnason et al[3] found age to be a significant risk factor for a new strain injury, independent of injury history. In the present study, age was associated with injury risk in the univariate analysis but not in the multivariate analysis.

Among other potential risk factors mentioned in the literature, reduced flexibility has been suggested as a risk factor for hamstring strains.[31] It has also been shown that soccer players are less flexible than a control group[9] and that soccer players often do not pay sufficient attention to stretching exercises.[2,11,17,19] A study from Australian rules football examining a simple way of measuring hamstring flexibility, the toe touch test, did not find it useful as a predictor of increased risk of hamstring strains in Australian rules football players.[6] The test used to measure hamstring muscle length in this study has been used in different studies.[3,13] Árnason et al[3] did not find hamstring muscle length to be a significant predictor of injury risk, which corresponds with the present findings. The coefficient of variation for the measurements from the passive knee extension test in this study was 9%, which means that the accuracy of the test is quite good. In other words, it seems that there is no association between hip flexion range of motion flexibility and hamstring injury risk, which may explain why stretching programs do not seem to influence injury risk.[1,28]

From a biological perspective, it seems reasonable to suggest that explosive athletes with a dominant fast muscle fiber type would be more prone to sustain strain injuries. In this study, however, neither the 40-m sprint test nor the countermovement jump test was associated with injury risk.

No registration of contact and noncontact injuries was made in this study. Contact injuries make up a much more heterogeneous group according to reasons for injury, and most of the potential and known intrinsic risk factors for injuries in male soccer are best applicable to noncontact injuries. However, to a player, the important issue is whether he is injured or not, and in this study, the main goal was to look at simple ways of measuring potential risk factors for injuries, not injury mechanisms. Hence, the injury report form was simplified to possibly improve compliance from the physiotherapists. One cannot eliminate the risk of contact and thereby contact injuries in soccer, and the risk factors tested in this study were therefore evaluated independently of contact or noncontact in the injury situation.

We did not record the mechanism of injury, and therefore, we do not know whether injuries resulted from contact with other players, although this is rarely the case with hamstring strains. If there were a number of contact injuries among the hamstring injuries recorded, these would presumably serve to dilute the effect of the risk factors studied. However, we cannot correct for this, as the mechanism of injury in each case is not known.

The present study is one of the largest cohort studies on risk factors for hamstring injuries to date, with as many as 76 injuries. Still, the statistical power is limited for multivariate tests. Nevertheless, the strength of the candidate risk factors studied does not indicate that any of these would be helpful as screening tools. As pointed out by Bahr and Holme[5] in their review, the present number of injuries should be sufficient to detect clinically relevant risk factors. In this study, overuse injuries in which no time loss had occurred were also included as hamstring injuries. As MRI or ultrasound examinations were not readily available, we did this to include small repeated strain injuries, as some players still elect to play despite discomfort in the posterior thigh. We cannot be sure that all of these represented true strain injuries to the hamstring muscles, but a separate statistical analysis using solely acute time-loss injuries as end point (data not shown) did not change the main findings.

One limitation of the current study is that we had to rely on the coaches for the exposure registration. We had no way to check their figures, but there should be no reason to misreport. If a game or practice session was missed, it would affect all players on the team, which is unlikely to influence the analysis regarding any specific risk factor. A more critical error would occur if the team physiotherapists were to misreport injuries, and this was related somehow to the risk factors under study. However, there should be no reason for the physiotherapist to intentionally misreport, and even if cases have been missed or misclassified, it may be expected that these would be unrelated to player characteristics. Also, there is a low injury incidence in this study compared with other studies, most of them from the highest level of soccer.[2,10,18,29,30] This could partly be explained by the lower level of play, but it could also be that our recording system did not capture all injuries. If that were the case, this may be expected to have influenced all risk factors, not any specific factor. Therefore, the greatest consequence of missing cases would be loss of statistical power.

CONCLUSION

In a multivariate analysis, a history of an acute hamstring injury was found to be a significant risk factor for new hamstring injuries. Previously injured players have more than twice as high a risk of sustaining a new hamstring injury. Other potential risk factors such as clinical findings, hamstring muscle length, jumping ability, a simple eccentric strength test, or running speed were not associated with increased risk in this study.

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REFERENCES

1. Arnason A, Andersen TE, Holme I, Engebretsen L, Bahr R. Prevention of hamstring strains in elite soccer: an intervention study. *Scand J Med Sci Sports*. 2008;18:40-48.
2. Arnason A, Gudmundsson A, Dahl HA, Johannsson E. Soccer injuries in Iceland. *Scand J Med Sci Sports*. 1996;6:40-45.
3. Arnason A, Sigurdsson SB, Gudmundsson A, Holme I, Engebretsen L, Bahr R. Risk factors for injuries in football. *Am J Sports Med*. 2004;32:5S-16S.
4. Askling C, Karlsson J, Thorstensson A. Hamstring injury occurrence in elite soccer players after preseason strength training with eccentric overload. *Scand J Med Sci Sports*. 2003;13:244-250.
5. Bahr R, Holme I. Risk factors for sports injuries: a methodological approach. *Br J Sports Med*. 2003;37:384-392.
6. Bennell K, Tully E, Harvey N. Does the toe-touch test predict hamstring injury in Australian Rules footballers? *Aust J Physiother*. 1999; 45:103-109.
7. Bennell K, Wajswelner H, Lew P, et al. Isokinetic strength testing does not predict hamstring injury in Australian Rules footballers. *Br J Sports Med*. 1998;32:309-314.
8. Croisier JL, Ganteaume S, Binet J, Genty M, Ferret JM. Strength imbalances and prevention of hamstring injury in professional soccer players: a prospective study. *Am J Sports Med*. 2008; 36:1469-1475.
9. Ekstrand J, Gillquist J. The frequency of muscle tightness and injuries in soccer players. *Am J Sports Med*. 1982;10:75-78.
10. Ekstrand J, Gillquist J. Soccer injuries and their mechanisms: a prospective study. *Med Sci Sports Exerc*. 1983;15:267-270.
11. Ekstrand J, Gillquist J, Moller M, Oberg B, Liljedahl SO. Incidence of soccer injuries and their relation to training and team success. *Am J Sports Med*. 1983;11:63-67.
12. Engebretsen AH, Myklebust G, Holme I, Engebretsen L, Bahr R. Prevention of injuries among male soccer players: a prospective, randomized intervention study targeting players with previous injuries or reduced function. *Am J Sports Med*. 2008;36:1052-1060.
13. Fredriksen H, Dagfinrud H, Jacobsen V, Maehlum S. Passive knee extension test to measure hamstring muscle tightness. *Scand J Med Sci Sports*. 1997;7:279-282.
14. Gabbe BJ, Bennell KL, Finch CF, Wajswelner H, Orchard JW. Predictors of hamstring injury at the elite level of Australian football. *Scand J Med Sci Sports*. 2006;16:7-13.
15. Gabbe BJ, Finch CF, Bennell KL, Wajswelner H. Risk factors for hamstring injuries in community level Australian football. *Br J Sports Med*. 2005;39:106-110.
16. Hagglund M, Walden M, Ekstrand J. Previous injury as a risk factor for injury in elite football: a prospective study over two consecutive seasons. *Br J Sports Med*. 2006;40:767-772.
17. Hawkins RD, Fuller CW. A preliminary assessment of professional footballers' awareness of injury prevention strategies. *Br J Sports Med*. 1998;32:140-143.
18. Hawkins RD, Fuller CW. A prospective epidemiological study of injuries in four English professional football clubs. *Br J Sports Med*. 1999;33:196-203.
19. Inklaar H. Soccer Injuries. II: aetiology and prevention. *Sports Med*. 1994;18:81-93.
20. Jarvinen TA, Kaariainen M, Jarvinen M, Kalimo H. Muscle strain injuries. *Curr Opin Rheumatol*. 2000;12:155-161.
21. Juma AH. Outline of sport injuries in the V World Youth Championship for FIFA Cup in Saudi Arabia. *Indian J Med Sci*. 1998;52: 433-437.
22. Junge A, Dvorak J. Soccer injuries: a review on incidence and prevention. *Sports Med*. 2004;34:929-938.
23. Lian O, Engebretsen L, Ovrebo RV, Bahr R. Characteristics of the leg extensors in male volleyball players with jumper's knee. *Am J Sports Med*. 1996;24:380-385.
24. Meeuwisse WH. Assessing causation in sport injury: a multifactorial model. *Clin J Sport Med*. 1994;4:166-170.
25. Mjolsnes R, Arnason A, Osthagen T, Raastad T, Bahr R. A 10-week randomized trial comparing eccentric vs. concentric hamstring strength training in well-trained soccer players. *Scand J Med Sci Sports*. 2004;14:311-317.
26. Noonan TJ, Garrett WE Jr. Injuries at the myotendinous junction. *Clin Sports Med*. 1992;11:783-806.

27. Roos EM, Roos HP, Lohmander LS, Ekdahl C, Beynnon BD. Knee Injury and Osteoarthritis Outcome Score (KOOS): development of a self-administered outcome measure. *J Orthop Sports Phys Ther*. 1998;28:88-96.
28. Thacker SB, Gilchrist J, Stroup DF, Kimsey CD Jr. The impact of stretching on sports injury risk: a systematic review of the literature. *Med Sci Sports Exerc*. 2004;36:371-378.
29. Walden M, Hagglund M, Ekstrand J. Injuries in Swedish elite football: a prospective study on injury definitions, risk for injury and injury pattern during 2001. *Scand J Med Sci Sports*. 2005; 15:118-125.
30. Walden M, Hagglund M, Ekstrand J. UEFA Champions League study: a prospective study of injuries in professional football during the 2001-2002 season. *Br J Sports Med*. 2005;39:542-546.
31. Witvrouw E, Danneels L, Asselman P, D'Have T, Cambier D. Muscle flexibility as a risk factor for developing muscle injuries in male professional soccer players: a prospective study. *Am J Sports Med*. 2003;31:41-46.

Appendix 1. Risk factor analyses where each leg was the unit of analysis, including both continuous (mean ± SEM) and categorical (yes/no) dependent variables. Comparisons of risk factors were made between hamstrings that sustained at least one injury during the following season ("Injured") and hamstrings that did not ("Uninjured"). P-values are the results from univariate analyses in STATA using generalized estimating equations taking into account the individual exposure and the fact that the left and the right leg belonged to the same player.

	Current injury							
		Uninjured (n=945)	Injured (n=65)					
	n	n/Mean ± SEM	n/Mean ± SEM	% injured	SD	OR	95% CI	p-value
Previous acute hamstring injury								
Yes	315	282	33	10.5%		2.62	[1.54-4.45]	<0.001
No	695	663	32	4.6%		1.00		
Missing	6							
Number of previous acute injuries								
No previous injury	695					1.00		
1 injury	155	143	12	7.7%		1.42	[0.73-2.77]	0.30
2 injuries	75	68	7	9.3%		1.56	[0.65-3.74]	0.32
3 injuries	34	30	4	11.8%		1.91	[0.61-6.00]	0.27
4 injuries	13	11	2	15.4%		2.49	[0.50-12.5]	0.27
5 injuries	5	4	1	20.0%		3.04	[0.30-31.2]	0.35
>5 injuries	33	26	7	21.2%		4.65	[1.83-11.8]	0.001
Time since previous injury (n=1016)								
Never	695					1.00		
0-6 months	66	57	9	13.6%		1.61	[0.70-3.67]	0.26
6-12 months	64	55	9	14.1%		1.52	[0.66-3.50]	0.32

1-2 years	83	74	9	10.8%		1.06	[0.47-2.40]	0.90
>2 years	101	95	6	5.9%		0.42	[0.16-1.05]	0.06
Missing	7							
HaOS function score[1]								
Total score	964	88.8 ± 0.4	83.3 ± 2.1		13.0	1.29	[1.08-1.54]	0.005
Symptoms	996	82.3 ± 0.8	74.2 ± 3.5		23.6	1.13	[1.02-1.25]	0.03
Soreness	994	86.6 ± 0.5	83.1 ± 1.9		14.0	1.15	[0.97-1.38]	0.12
Pain	996	91.2 ± 0.4	85.9 ± 1.9		11.8	1.33	[1.11-1.60]	0.003
Function in sports	1000	95.1 ± 0.4	91.2 ± 1.9		11.9	1.21	[1.02-1.43]	0.03
Quality of life	1001	89.1 ± 0.6	81.4 ± 2.6		17.9	1.21	[1.07-1.37]	0.003
Clinical examination								
Clinically short hamstrings (n=893)								
Yes	305	286	19	6.2%		0.99	[0.53-1.85]	0.98
No	588	552	36	6.1%		1.00		
Tender hamstrings (n=893)								
Yes	17	16	1	5.9%		1.08	[0.12-9.41]	0.95
No	876	822	54	6.2%		1.00		
Hamstring length (degrees)	1005	117.3 ± 0.5 (940)	116.8 ± 2.1 (65)		16.2	0.96[2]	[0.81-1.13]	0.63

[a] The number of legs in the uninjured and injured groups reflect the number of legs that completed each of the tests.

[1] All results (OR and 95% CI) are presented for a reduction of 10 in hamstring function score (HaOS).

[2] Per decrease of one standard deviation.

Range (mean, min-max) of continuous variables: HaOS (Total score: 88.5, 30.6-100.0), (Symptoms: 81.8, 0.0-100.0), (Soreness: 86.4, 25.0-100.0), (Pain: 90.9, 34.4-100.0), (Sport: 94.9, 25.0-100.0), (Quality of Life: 88.6, 12.5-100.0), Hamstring muscle length (117.2, 64.0-172.0).

Appendix 2. Risk factor analyses where each player was the unit of analysis, including both continuous (mean ± SEM) and categorical (yes/no) dependent variables. Players who sustained at least one hamstring injury during the following season ("Injured") and the players who did not ("Uninjured") were compared. P-values are the results from logistic regression analyses performed in SPSS.

	Current injury							
		Uninjured (n=447)	Injured (n=61)					
Factor	n	Mean ± SEM	Mean ± SEM	% injured	SD	OR	95% CI	p-value
Age (years)	500	23.9 ± 0.2 (439)	24.8 ± 0.6 (61)		4.2	1.25[1]	[0.96-1.63]	0.09
Height (cm)	497	181.4 ± 0.3 (436)	181.5 ± 0.7 (61)		6.3	1.01[1]	[0.77-1.33]	0.92
Weight (kg)	493	77.9 ± 0.4 (433)	78.2 ± 0.9 (60)		9.3	1.05[1]	[0.77-1.43]	0.76
BMI (kg * m^{-2})	486	23.7 ± 0.1 (426)	23.7 ± 0.2 (60)		2.1	1.02[1]	[0.72-1.43]	0.91
Player position	485							0.09
Forward	84	72	12	14.3		1.00		
Winger	70	64	6	8.6		0.56	[0.20-1.59]	0.28
Attacking midfielder	62	55	7	11.2		0.76	[0.28-2.07]	0.60
Central midfielder	66	63	3	4.5		0.29	[0.08-1.06]	0.06
Wingback	87	71	16	18.4		1.35	[0.60-3.06]	0.47
Center back	71	59	12	16.9		1.22	[0.51-2.92]	0.65
Goalkeeper	45	43	2	4.4		0.28	[0.06-1.31]	0.11
Level of play	508							0.82
1st division	119	106	13	10.9		1.00		
2nd division	256	223	33	12.9		1.21	[0.61-2.39]	0.59
3rd division	133	118	15	11.3		1.04	[0.47-2.28]	0.93

Level of play last season								0.88
Elite division	4	3	1	25.0		1.00		
1st division	126	110	16	12.7		0.44	[0.04-4.45]	0.48
2nd division	154	136	18	11.7		0.40	[0.04-4.02]	0.43
3rd division or lower	201	177	24	11.9		0.41	[0.04-4.07]	0.44
Junior or senior national team matches								
Yes	92	81	11	12.0		0.99	[0.50-1.99]	0.99
No	416	366	81	19.5		1.00		
Specific tests								
Counter movement jump test	423	37.7 ± 0.2 (376)	37.6 ± 0.6 (47)		4.7	0.99[1]	[0.73-1.34]	0.95
Nordic hamstring strength test (n=452)	452							
Weak	173	157	16	9.3		1.00		
Strong	279	244	35	12.5		1.41	[0.75-2.63]	0.28
40 m sprint test	398	5.20 ± 0.01 (355)	5.20 ± 0.03 (43)		0.18	0.99[1]	[0.72-1.35]	0.95

[a] The number of players in the uninjured and injured groups reflect the number of players who completed each of the tests.
[1] Per increase of one standard deviation.
Range (mean, min-max): Counter movement jump test (37.7, 25.9-56.8) and 40 meter sprint test (5.20, 4.71-5.81).

Paper V

Intrinsic risk factors for groin injuries among male soccer players – a prospective cohort study

*Engebretsen AH, MD [1] **

Myklebust G, PT, PhD [1]

Holme I, PhD [1]

Engebretsen L, MD PhD [1, 2]

Bahr R, MD PhD [1]

[1] Oslo Sports Trauma Research Center
Norwegian School of Sports Sciences
PO Box 4014 Ullevål Stadion
N-0806 Oslo
Norway

[2]Department of Orthopaedic Surgery
Ulleval University Hospital
University of Oslo
N-0407 Oslo
Norway

Corresponding Author:
*Engebretsen AH, MD
Oslo Sports Trauma Research Center
Norwegian School of Sports Science
PO Box 4014 Ullevål Stadion
N-0806 Oslo
Norway
Tel: (+47) 23 26 23 57
Fax: 23 26 23 07
E-mail: Anders.Engebretsen@nih.no

Key terms: Groin injuries; football; risk factors; prospective cohort study; previous injuries.

Abstract

Background: This study was conducted to see if we could identify risk factors for groin injuries among male soccer players.

Hypothesis: We hypothesized that previous groin injuries, reduced function scores, age, findings on clinical examination and low isometric groin strength is associated with increased risk of new groin injuries.

Study design: Prospective cohort study.

Methods: A total of 508 players representing 31 amateur teams were tested during the 2004 preseason for potential risk factors for groin injury through a questionnaire on previous injury and function score (Groin Outcome Score; GrOS) and a clinical examination of the groin. Generalized estimating equations were used in univariate analyses to identify candidate risk factors, and factors with a p-value of <0.10 were then examined in a multivariate model.

Results: During the soccer season, 61 groin injuries, affecting 55 legs (51 players), were registered. The total incidence of groin injuries was 0.6 injuries per 1000 playing hours (95% CI 0.4 to 0.7), 0.3 injuries per 1000 training hours (95% CI 0.2 to 0.4) and 1.8 injuries per 1000 match hours (95% CI 1.2 to 2.5). In a multivariate analysis, previous acute groin injury (adjusted OR 2.60, 95% CI 1.10 to 6.11) and weak adductor muscles as determined clinically (adjusted OR 4.28, 95% CI 1.31 to 14.0) were significantly associated with increased risk of groin injuries.

A multivariate analysis based on acute time-loss injuries only revealed the 40 m sprint test result (adjusted OR 2.03 for 1SD change (injured group faster), 95% CI 1.06 to 3.88, p=0.03) and functional testing of the abdominal muscles (adjusted OR 15.5 (4% scored as weak in the uninjured group compared to none in the injured group), 95% CI 1.11 to 217, p=0.04) as significant risk factors.

Conclusions: A history of previous acute groin injury and weak adductor muscles were significant risk factors for new groin injuries.

Introduction

Strain injuries to the groin are among the most common injuries in adult male soccer and the incidence has been reported to be 1.0[15] and 1.1[33] per 1000 playing hours, accounting for 11-16% of all injuries.[5, 13, 15, 16, 32, 33] Also, a vicious circle with recurrent groin strains may occur, resulting in a recurrent problem.[33] Hence, primary and secondary prevention are equally important.

To identify the athlete at risk and possibly even correct the predisposing factor(s), the specific intrinsic and extrinsic risk factors for the injury type in question must be known.[25] Regarding intrinsic risk factors in soccer, it seems that previous groin injury places an athlete at increased risk of suffering a strain injury of the groin, especially when rehabilitation is inadequate.[1, 14] Also age has been suggested as a risk factor for injuries.[1]

Other potential risk factors are mentioned in the literature from different sports, but the results and study groups differ widely. These include high level of play,[20] age,[7] core stability[3, 22], decreased range of motion in hip abduction[1] and weak adductor muscles and abnormal muscle ratios.[6, 31]

To examine the contribution of the various risk factors of injuries and etiology and to explore their interrelationship, it is necessary to include all candidate factors in a multivariate analysis.[25] Even though a large number of risk factor studies have been carried out, only a few of them have used this approach.[24] We therefore planned the present prospective cohort study on soccer players to screen for several potential risk factors for groin injuries, some of which have not been studied in depth earlier.

Elite players only constitute a small portion of all soccer players, and advanced resources for screening tests are not available for the majority of players. Therefore, one goal of this study was to investigate if simple screening tests, which are easy to do and do not require advanced equipment, can be used to identify individuals at risk. In this way, if a self-report questionnaire on groin function and symptoms or simple strength/sprint tests used in this study were shown to be useful, teams and players with no medical staff can test themselves in the pre-season to find out whether they have an increased risk of injuries.

We included clinical examination performed by experienced physicians for comparison with the simple self-assessment and to see if such an examination could predict injury risk. In addition, counter movement jump test and 40m sprint test were included in order to investigate if explosive athletes with a dominant fast-twitch muscle fiber type would be more prone to strain injuries, and if it could be evaluated through such tests. Also, as weak adductors have been suggested as risk factors for groin injury in ice hockey,[31] and strengthening exercises have been introduced as well-documented treatment of adductor-related groin pain and also suggested as possible means of preventing injuries,[19] the isometric adductor strength test was included.

We hypothesized that previous acute groin injuries, reduced function scores, weak groin muscles or abnormalities on a clinical examination could predict increased risk of new groin injuries. In addition, we included clinical examination and self-reported player information such as age, height, weight, BMI, level of play and player position to investigate if there were any correlations between these variables and injury risk.

Hence, the aim of this study was to examine potential intrinsic risk factors for acute and overuse groin strain injuries in a prospective cohort study among sub-elite male soccer players.

Methods

Design and participants

This study is based on data from a randomized trial on male amateur soccer players examining the effect of a training program designed to prevent injuries. The design, the intervention program, and the results of the study have previously been described in detail in a separate paper.[8] Because no differences were seen in injury rates between the intervention and control groups,[8] the entire cohort could be used to assess the effect of a number of risk factors assessed at baseline.

A total of 35 teams (n=769 players) from the Norwegian 1st, 2nd or 3rd division of soccer for men, geographically located in the proximity of Oslo, were invited to participate in the study. In Norway there are several different 3rd division conferences, and the 3rd division teams included either won their conference or finished as first runners up the previous season, resulting in a relatively homogenous group of teams, even if the 35 teams competed in three different divisions. Three of the teams (n=60 players) declined the invitation to participate, 177 players did not report for testing, three players did not speak Norwegian and could therefore not complete the questionnaire and four players were excluded for other reasons (Figure 1). Hence, 244 of the players invited could not be included. In addition, one team (n=17 players) was later excluded because the physiotherapist did not record injuries, resulting in a final sample of 508 players representing 31 teams from three divisions (1st division, n=7, 122 players; 2nd division, n=16, 260 players; and 3rd division, n=8; 126 players). The study was approved by the Regional Committee for Medical Research Ethics, Helse Øst, and written consent was obtained.

Risk factor screening

The teams were tested for potential risk factors for groin injuries during the 2004 pre-season, January through March, at the Norwegian School of Sport Sciences. Every player capable (not injured at the time) completed three counter movement jumps, two 40 m sprint tests, an isometric adductor strength test, a clinical examination and a questionnaire.

The counter movement jump test was performed on a force plate (AMTI LG6-4-1, Advanced Mechanical Technology, Inc., Watertown, MA, USA), with hands held at the hips as described by Lian et al.[23] From a standing position with straight knees the player squatted down to at least 90° before jumping as high as he could. All three tests were scored as the maximal height of rise of the center of gravity in centimeters, calculated based from data on body weight and ground reaction forces on the force plate during the jump. The best result was used for the analysis.

The 40 m sprint test was performed with a contact mat and double beam timing gates at the Norwegian Olympic Training Center, measuring the time from when the front foot left the floor to the time sensor at 40 m.

The clinical testing of the players was performed by a group of ten sports physical therapists and sports physicians who were blinded for any injury history (scars were not concealed). In accordance with the FIFA F-FMARC pre-season medical assessment,[4] both legs were examined for hip flexibility and range of motion, pain at palpation of adductor muscles, short adductor muscles, pain in adduction against resistance, painful muscle insertions of the adductor longus muscle, rectal abdominal muscles or at the pubic bone, pain in passive stretching of the adductors and functional testing of the rectal abdominal muscles.

All players were tested twice on each leg for isometric adductor strength measured using a hand-held dynamometer (Hydraulic Push-Pull Dynamometer, Baseline® Evaluation

Instruments, White Plains, NY, USA) similar to Krause et al. (2007).[21] The tests were conducted with the players lying in supine position on a bench, keeping the leg extended. The dynamometer was positioned 5 cm proximal to the medial ankle malleolus. The dynamometer was held stationary while the player pushed maximally against the resistance. The arms were held alongside the body during the test. Both legs were tested, with two maximal contractions for each test variable and a 10 s rest period between the two attempts, and the highest value for each leg was registered.

The players also completed a questionnaire in two parts, where the first part covered general player information (age, height, body mass index, position on the field, number of junior or senior national team matches played, level of play this season, and level of play the previous season), and self-reported history of previous groin injuries (number, severity, nature and number of months since the most recent acute groin injury and if the most recent injury had caused the player to miss matches). The second part was a function score for the groin (Groin Outcome Score; GrOS[8]), which was developed as a screening tool. This form has a similar outline as the KOOS form,[28] which consists of five major parts (symptoms, pain, activities of daily life, function in sports and recreation, quality of life) and is scored by calculating the mean value of the five parts in percent of the total possible score, where 100% is the maximal and 0% the lowest score. For the GrOS, we replaced the category “function in daily living” with a category on muscle soreness resulting in five categories (symptoms, pain, soreness, function in sports and quality of life).

In addition, a similar screening was done for risk factors for ankle, knee and hamstring injuries. The data from these tests are/will be reported in separate papers.[9-11]

Injury reporting

An injury was defined as any physical complaint sustained by a player that resulted from a soccer match or soccer training, forcing the player to miss or being unable to take full part in future soccer training or match play ("time-loss" injury). Acute injuries were defined as injuries with a sudden onset associated with a known trauma, whereas overuse injuries were those with a gradual onset without any known trauma. There is no consensus on definitions or diagnostic criteria for groin injuries[17, 18] and the diagnosis is difficult. Therefore, based on information on injured region, injury type and diagnosis in the injury reports from the physiotherapists, two of the authors who were blinded to all other information regarding risk factors classified all injuries as a groin injury or not. For the purpose of the present paper, an injury was classified as groin injury if it was recorded as either an acute or an overuse injury of the inside thigh/groin area.

Injuries were classified into three severity categories according to the time it took until the player was fully fit to take part in all types of organized soccer play: minor (1-7 days), moderate (8-28 days) and major (>28 days). However, overuse injuries where there was no time loss were also included to incorporate small repeated strain injuries, as some players still elect to play despite discomfort in the groin. The head coach for every team registered each player's participation in training and the number of minutes played in matches.

The team physical therapist was responsible for reporting injuries on their team throughout the preseason and the season. Most of the teams from the 1st and 2nd division already had a physical therapist working with the team. In case there was no physical therapist involved, we assigned one for the team. However, the physical therapist was not required to be present at every training session and match; the degree of follow-up therefore varied from team to team participating in the study.

Reliability testing

Inter-test reliability tests were done for the adductor strength test by having the same player repeat the same test with different personnel after he had completed the first test. Each examiner was blinded to the other's results. The same scoring system/clinical forms were used at both stations. The coefficient of variation for the continuous variable adductor strength was calculated as the standard deviation of the difference between the first and second test as a percentage of the average test results for both tests.

Statistical methods

Exposure to matches and training was calculated by adding the individual duration of all training and match play during the season.

For the continuous dependent variable risk factor analyses, where each leg was the unit of analysis, generalized estimating equations (STATA, version 8; STATA, Texas, U.S.A.) were used, accounting for total individual exposure during the soccer season, any within-team correlations and the fact that the left and right foot belonged to the same player. Logistic regression analyses were used to analyse the relationships between per subject calculated dichotomous injury variables and their risk factors.

All risk factor variables were examined in univariate analyses, and those with a P value <0.10 were investigated further in a multivariate model.

Results

The total incidence of injuries during the season was 4.7 injuries per 1000 playing hours (95% CI 4.3 to 5.1), 12.1 (95% CI 10.5 to 13.7) for match injuries and 2.7 (95% CI 2.4 to 3.1) for training injuries. The total exposure to match play and training was 108 111 player hours.

A total of 61 groin injuries were reported, affecting 55 legs and 51 (10.0%) of the 508 players in the study. The total incidence of groin injuries was 0.6 injuries per 1000 playing hours (95% CI 0.4 to 0.7), 0.3 injuries per 1000 training hours (95% CI 0.2 to 0.4) and 1.8 injuries per 1000 match hours (95% CI 1.2 to 2.5).

A total of 44 players sustained one groin injury, five sustained two injuries, one sustained three injuries and one player sustained four injuries.

Of the 61 injuries, 31 occurred on the right side and 30 on the left. There were 22 acute and 39 overuse groin injuries reported. Of these, 29 were minor injuries (time loss 1 to 7 days), 17 moderate injuries (8 to 28 days) and 12 severe injuries (>28 days), while information on the duration of time loss was missing in one case. In two overuse injuries there was no time loss.

The coefficient of variation for the continuous variable adductor strength was 19.6%.

Univariate analyses (Table 1, online appendix) revealed the following potential leg-dependent risk factors for groin injuries; previous acute groin injury, total GrOS and GrOS sub scores “symptoms”, “soreness” and “pain” and the clinical tests pain at external rotation in the hip joint and reduced range of motion for external rotation, pain at functional testing of the rectal abdominal muscles, weak adductor muscles determined clinically, pain at functional testing of the iliopsoas muscles and weak ilipsoas muscles determined clinically.

Of the player-dependent factors, age and counter movement jump test were significantly associated with risk of groin injury (Table 2, online appendix). Because this study is based on data from a randomized trial, separate analyses controlling for group assignment (intervention or control group) were performed; however, with no change in the results. Also, a Poisson model approximating multinomial logistic regression analyses was used, in order to compare players who sustained no injuries versus those who sustained one injury versus those who sustained more than one injury. Again, the results did not differ from the original analyses.

In cases where two of the potential leg-dependent risk factors were strongly intercorrelated ($p<0.05$), only the most clinically relevant test was included in the final multivariate analysis. This includes pain at external rotation in the hip joint and reduced range of motion for external rotation (intercorrelation p=0.02) (pain at external rotation chosen due to greater clinical relevance) and weak ilipsoas muscles determined clinically versus pain at functional testing (intercorrelation p=0.02) (weak ilipsoas muscles chosen because this was believed to be clinically more specific).

Risk factors with p-value of <0.10 were then considered as candidates to predict which players are more prone to sustain a groin injury. Because these factors may be intercorrelated or confounded by each other, a multivariate analysis was performed which showed that previous acute groin injury (adjusted OR 2.60, 95% CI 1.10 to 6.11) and weak adductor muscles determined clinically (adjusted OR 4.28, 95% CI 1.31 to 14.0) were significant predictors of increased risk of groin injuries. Out of 1016 cases, the final multivariate analysis was based on 560 cases after cases with missing data were excluded.

We also completed a separate statistical analysis using acute time-loss injuries only. The univariate analyses identified the 40 m sprint test, counter movement jump test and level of play as additional potential player-dependent risk factors, while previous acute groin injury, GrOS and functional testing of the abdominal muscles were identified as potential leg-dependent risk factors. A multivariate analysis based on acute time-loss injuries only revealed the 40 m sprint test result (adjusted OR 2.03 for 1SD change (injured group faster), 95% CI 1.06 to 3.88, p=0.03) and functional testing of the abdominal muscles (adjusted OR 15.5 (4% scored as weak in the uninjured group compared to none in the injured group), 95% CI 1.11 to 217, p=0.04) as significant risk factors.

Discussion

The main finding of this cohort study investigating potential risk factors for groin injuries in soccer was that a history of previous acute groin injury and weak adductor muscles are significant risk factors. Previously injured players have more than twice as high risk of sustaining a new groin injury, while players with weak adductor muscles have a four times higher injury risk. Other candidates for identification of players with increased risk of groin injuries were age, counter movement jump test, groin function score and clinical examination of external rotation, abdominal and iliopsoas muscles. However, none of these held up in the multivariate analysis. Among other potential predictors, such as isometric adductor strength and function, 40 m sprint speed, level of play or other self-reported player characteristics, none were associated with increased risk in this study.

Previous injury seems to be the most consistent intrinsic risk factor identified in the literature. A systematic review examining risk factors for acute muscle strains in different sports found previous injury to be a strong predictor of muscle strain injury.[6] In a multivariate analysis in the largest cohort study to date in male soccer, previously injured players were found to have more than a seven-fold increased risk of sustaining new groin injuries compared with uninjured controls.[1] A study from Swedish elite soccer also found previous injury to the same leg to be a significant risk factor.[14] These findings are consistent with studies from other sports with high demands on the groin area, as well.[24] The results from the present study are in accordance to these findings, and underline the importance of adequate rehabilitation before full return to play. Also, they suggest that preventing the first injury should be a high priority, to keep players from entering the vicious cycle of recurrent injuries to the same body part. To accomplish this, the best method may be strength exercises. While a passive physical therapy programme of massage, stretching and modalities was ineffective in treating chronic groin strains, Hölmich et al[19] demonstrated that an 8- to 12-week active strengthening programme, consisting of progressive resistive adduction and abduction exercises, balance training, abdominal strengthening and skating movements on a slide board, was effective in treating chronic groin strains. A randomized controlled trial in Norwegian male soccer using a modified shortened version of this programme did not find a preventive effect.[8] However, due to poor compliance it is not possible to say whether the shortened programme would have been effective, if completed as prescribed. Also, in professional ice hockey adductor strengthening exercises reduced the number of groin injuries.[30]

The other main observation in the present study was that players assessed to have weak adductors in the clinical examination had four times the injury risk of players with normal strength. No publications exist from male soccer on the topic, but in a study from male elite ice hockey, significantly lower adductor strength was found among injured players.[31] However, in contrast to the clinical examination, adductor strength measured by a handheld dynamometer was not significantly associated with risk of injury. Still, the coefficient of variation for this test of 19.6% indicates that inter-test reliability was poor.

Hip and groin injuries are reported to often occur in sports involving side-to-side cutting, quick accelerations and decelerations, and sudden directional changes.[26] Strength imbalances between the propulsive muscles and the stabilizing muscles of the hip and pelvis[12] and between the synergistic abductors and adductors have been suggested as risk factors for groin injuries.[24] Also, delayed contraction of the transversus abdominis,[3] as a measure of reduced core stability, has been suggested in the literature. Unfortunately, based on the tests performed in this study, these hypotheses can not be addressed.

Neither this nor previous studies[1, 31] have identified adductor length as a risk factor for groin injury in soccer, and stretching programs do not seem to influence injury risk.[29] A study from Belgian elite soccer found no predictive value of adductor flexibility measurements.[34] Still, Arnason et al. found decreased range of motion in hip abduction to be a significant risk factor for groin injuries, which is in contrast with the present findings. In the present study, however, hip range of motion was only examined clinically.

Age and experience have been suggested as risk factors in elite ice hockey.[7] The present study found these factors to be strongly associated with injury risk in the univariate, but not in the multivariate analysis. This is in accordance with previous studies from soccer[1] and other sports.[7, 27]

It seemed reasonable to hypothesize that explosive athletes with a dominant fast-twitch muscle fiber type would be more prone to strain injuries. However, in this study neither the 40 m sprint test nor the counter movement jump test result was associated with injury risk in the main analysis. This is in accordance with Arnason et al, who found no predictive effect of jump tests.[1] However, it should be noted that using acute time-loss injuries only as the end point identified the 40 m sprint test and functional testing of the abdominal muscles as significant risk factors. This could indicate that the risk for acute injuries is increased among "explosive" players, and that previous injury is less important as risk factor for new acute injuries. However, as this analysis is based on only 22 acute time-loss injuries it needs to be interpreted with caution.

The present study is one of the largest cohort studies on risk factors for groin injuries to date, with as many as 61 groin injuries in total. Still, the statistical power is limited for the multivariate tests, where a number of subjects had to be excluded because of missing test data. Nevertheless, the odds ratios of the candidate risk factors included do not indicate that any of these would be helpful as screening tools. As pointed out by Bahr & Holme [2] in their review, the present number of injuries should be sufficient to detect clinically relevant risk factors.

Overuse injuries where no time-loss had occurred were also included in our definition of groin injuries. As MRI or ultrasound examinations were not readily available we did this to include painful conditions about the groin, because some players still elect to play despite discomfort in the area. However, we can not be sure if all of these represented true strain injuries to the groin muscles.

This study was carried out among subelite male soccer players, and should not be extrapolated to other sports, females, youth players or other levels of play.

Conclusions

Using multivariate analyses, a history of a previous acute groin injury and weak adductor muscles were found to be significant risk factors for new groin injuries. Previously injured players have a more than twice as high risk of sustaining a new groin injury, while the risk is four times higher in players with weak adductor muscles.

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Fig 1. Flow chart showing movement of numbers of players participating.

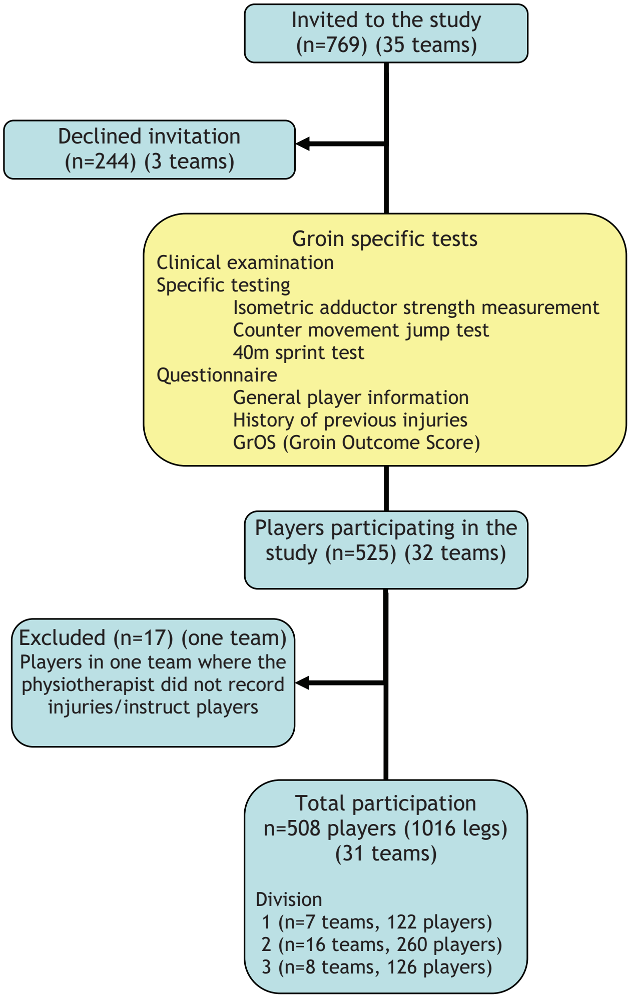

Table 1. Odds ratios for the risk of groin injury, calculated from generalized estimating equations taking into account the individual exposure and the fact that the left and the right leg belonged to the same player. Each leg was the unit of analysis, including both continuous (mean ± SEM) and categorical (yes/no) independent variables.

	Current injury							
		Uninjured legs (n=958)	Injured legs (n=55)					
	n	n/Mean ± SEM	n/Mean ± SEM	% injured	SD	OR	95% CI	p-value
Previous injuries								
Previous acute groin injury								
Yes	352	322	25	7.8		2.46	[1.38-4.37]	0.002
No	662	637	30	4.5		1.00		
Missing	2							
Number of previous acute groin injuries								
No previous injury	662	637	25	3.8		1.00		
1 injury	188	172	16	8.5		1.94	[1.03-3.66]	0.04
2 injuries	68	65	3	4.4		0.67	[0.17-2.69]	0.57
3 injuries	35	31	4	11.4		2.42	[0.78-7.46]	0.12
4 injuries	17	15	2	11.8		2.35	[0.48-11.5]	0.29
5 injuries	5	4	1	20.0		5.46	[0.50-59.5]	0.16
>5 injuries	39	35	4	10.3		2.18	[0.68-6.96]	0.19
Time since previous groin injury (n=1016)								0.89
Never	662	637	25	3.8		1.00		
0-6 months	91	83	8	8.8		1.40	[0.57-3.43]	0.47
6-12 months	69	63	6	8.7		2.36	[0.96-5.78]	0.06
1-2 years	72	66	6	8.3		1.86	[0.76-4.56]	0.18

>2 years	116	106	10	8.6		1.78	[0.84-3.80]	0.14
Missing	6							
GrOS* function score[1]								
Total score	926	84.7 ± 0.4	80.2 ± 2.1		12.7	1.27	[1.04-1.54]	0.02
Symptoms	1009	78.9 ± 0.8	71.4 ± 4.3		25.7	1.12	[1.02-1.25]	0.03
Soreness	995	90.9 ± 0.5	85.2 ± 2.3		14.1	1.24	[1.04-1.46]	0.01
Pain	993	93.4 ± 0.4	90.0 ± 1.8		11.5	1.22	[1.00-1.50]	0.05
Function in sports	992	95.4 ± 0.4	93.2 ± 1.7		11.3	1.14	[0.93-1.41]	0.22
Quality of life	965	64.6 ± 0.5	63.1 ± 1.7		14.4	1.10	[0.89-1.37]	0.38
Specific testing								
Isometric adductor strength[2]	948	24.8 ± 0.2	24.3 ± 0.8		6.0	0.93	[0.69-1.25]	0.61
Clinical examination								
Range of motion in hip joint								
Flexion (degrees)[2]	872	120.8 ± 0.5 (n=820)	123.7 ± 1.5 (n=52)		13.9	0.95	[0.71-1.28]	0.74
Extention (degrees)[2]	889	20.9 ± 0.3 (n=837)	19.7 ± 1.1 (n=52)		8.3	1.15	[0.85-1.55]	0.37
External rotation (degrees)[2]	898	46.3 ± 0.4 (n=846)	42.3 ± 1.8 (n=52)		12.2	1.53	[1.13-2.07]	<0.01
Internal rotation (degrees)[2]	899	29.8 ± 0.5 (n=847)	27.5 ± 2.0 (n=52)		13.5	1.06	[0.77-1.44]	0.73
Abduction (degrees)[2]	887	51.0 ± 0.4 (n=836)	52.1 ± 1.6 (n=51)		11.7	0.95	[0.70-1.28]	0.73
Pain in range of motion in hip joint								
Pain at adduction (n=900)								
Yes	53	49	4	7.5		1.19	[0.39-3.59]	0.76
No	847	799	48	5.7		1.00		

Pain at external rotation (n=898)							
Yes	18	15	3	16.7	3.51	[0.97-12.7]	0.06
No	880	831	49	5.6	1.00		
Pain at internal rotation (n=900)							
Yes	46	42	4	8.7	1.73	[0.56-5.34]	0.34
No	853	805	48	5.6	1.00		
Pain at abduction (n=887)							
Yes	31	27	4	12.9	2.30	[0.75-7.04]	0.15
No	856	809	47	5.5	1.00		
Adductor muscles							
Adductor muscles (n=892)							
Short	94	87	7	7.4	1.39	[0.58-3.31]	0.46
Normal	798	753	45	5.6	1.00		
Tender long adductor muscle insertion (n=900)							
Yes	275	258	17	6.2	1.39	[0.75-2.57]	0.30
No	625	590	35	5.6	1.00		
Pain at adduction against resistance (n=900)							
Yes	105	96	9	8.6	1.86	[0.85-4.07]	0.12
No	795	752	43	5.4	1.00		
Strength of adductor muscles (n=809)							
Weak	45	38	7	15.6	3.10	[1.20-8.03]	0.02
Normal	764	724	40	5.2	1.00		
Passive stretching of the adductors (n=900)							
Painful	62	56	6	9.7	1.89	[0.75-4.77]	0.18

No pain	838	792	46	5.5	1.00		
Rectal abdominal muscles and pubic joint							
Palpation of the pubic joint (n=900)							
Painful	208	194	14	6.7	1.23	[0.62-2.45]	0.55
No pain	692	654	38	5.5	1.00		
Palpation of the insertion of the rectal abdominal muscles (n=900)							
Painful	152	141	11	7.2	1.54	[0.74-3.21]	0.25
No pain	748	707	41	5.5	1.00		
Functional testing of the rectal abdominal muscles (n=900)							
Pain referred to the abdominal area	14	10	4	28.6	14.6	[3.86-55.2]	<0.001
No pain referred to the abdominal area	886	838	48	5.4	1.00		
Strength of the rectal abdominal muscles (n=882)							
Weak	36	34	2	5.6	0.77	[0.17-3.53]	0.74
Normal	846	796	50	5.9	1.00		
Major psoas and iliopsoas muscles							
Tender major psoas muscles (n=900)							
Yes	122	116	6	4.9	1.48	[0.88-2.49]	0.14
No	778	732	46	5.9	1.00		
Functional testing of the iliopsoas muscles (n=900)							
Painful	35	29	6	17.1	3.80	[1.34-10.8]	0.01
No pain	865	819	46	5.3	1.00		

Strength of the iliopsoas muscles (n=819)							
Weak	20	17	3	15.0	5.18	[1.41-19.1]	0.01
Normal	799	757	42	5.3	1.00		
Muscle length of iliopsoas (n=898)							
Normal	715	678	37	5.2	1.64	[0.85-3.18]	0.14
Shortened	183	168	15	8.2	1.00		

[a] The number of legs in the uninjured and injured groups reflect the number of legs that completed each of the tests.

[1] All results (OR and 95% CI) are presented for a reduction of 10 in GrOS-score.

[2] Results (OR and 95% CI) are presented per change of one standard deviation.

Range (mean,min-max) of continuous variables: GrOS total score: 84.5, 31.4-100.0; Symptoms: 78.5, 0.0-100.0; Soreness: 90.5, 25.0-100.0; Pain: 93.2, 36.5-100.0; Sport: 95.3, 18.8-100.0; Quality of Life: 64.5, 16.7-100.0; Adductor strength 24.8, 5.0-44.0; Range of motion for flexion 121, 85-155; extention 20.9, 0-45; external rotation 46.1, 5-85; internal rotation 29.6, 0-80; and abduction 51.1, 25-85.

Table 2. Odds ratios for the risk of groin injury, calculated by logistic regression analyses. Each player was the unit of analysis, including both continuous (mean ± SEM) and categorical (yes/no) independent variables.

	Current injury							
		Uninjured players (n=457)	Injured players (n=51)					
	n	Mean ± SEM	Mean ± SEM	% injured	SD	OR	95% CI	p-value
Age (years)	500	23.8 ± 0.2 (450)	25.9 ± 0.7 (50)		4.2	1.61[1]	[1.21-2.15]	0.001
Height (cm)	497	181.4 ± 0.3 (447)	181.2 ± 0.9 (50)		6.3	0.98[1]	[0.73-1.30]	0.86
Weight (kg)	493	77.9 ± 0.4 (445)	78.1 ± 1.1 (48)		9.3	1.02[1]	[0.72-1.44]	0.91
BMI (kg * m^{-2})	486	23.7 ± 0.1 (438)	23.7 ± 0.2 (48)		2.1	1.00[1]	[0.69-1.46]	0.98
Player position	485							0.37
Forward	84	77	7	8.3		1.00		
Winger	70	59	11	15.7		2.05	[0.75-5.61]	0.16
Attacking midfielder	62	57	5	8.1		0.97	[0.29-3.20]	0.95
Central midfielder	66	59	7	10.6		1.31	[0.43-3.93]	0.64
Wingback	87	82	5	5.7		0.67	[0.20-2-20]	0.51
Center back	71	61	10	14.1		1.80	[0.65-5-01]	0.26
Goalkeeper	45	42	3	6.7		0.79	[0.19-3.20]	0.74
Level of play	508							0.55
1st division	119	104	15	12.6		1.00		
2nd division	256	233	23	9.0		0.68	[0.34-1.37]	0.28
3rd division	133	120	13	9.8		0.75	[0.34-1.65]	0.48
Junior or senior national team matches	508							
Yes	92	82	10	10.9		1.12	[0.54-2.32]	0.77
No	416	375	41	9.9		1.00		

Specific tests							
Counter movement jump test	423	37.5 ± 0.2 (381)	39.1 ± 0.8 (42)	4.7	1.36[1]	[1.01-1.85]	0.05
40 meter sprint test	398	5.20 ± 0.01 (361)	5.16 ± 0.03 (37)	0.18	1.28[1]	[0.91-1.91]	0.16

[a] The number of players in the uninjured and injured groups reflect the number of players who completed each of the tests

[1] Per increase of one standard deviation

Range (mean, min-max): Counter movement jump test 37.7, 25.9-56.8 and 40 meter sprint test 5.20, 4.71-5.81.

Table 3. Multivariate analysis of the potential risk factors with $p<0.10$ in univariate analyses. P-values are the results from analysis in STATA using generalized estimating equations.

Risk factors		Adjusted OR	95% CI	p-value
Player dependent factors				
	Age[1]	1.10	[0.74-1.63]	0.65
	Counter movement jump test[1]	1.01	[0.89-1.14]	0.92
Leg dependent factors				
	Previous acute groin injury (yes/no)	2.60	[1.10-6.11]	0.03
	GrOS total score	1.04	[0.78-1.41]	0.77
	Clinical examination			
	External rotation in the hip joint (painful or not)	2.90	[0.55-15.2]	0.21
	Functional testing of rectal abdominal muscles (painful or not)	0.89	[0.28-2.79]	0.84
	Strength of adductor muscles (weak or not weak)	4.28	[1.31-14.0]	0.02
	Strength of iliopsoas muscles (weak or not weak)	2.23	[0.39-12.7]	0.36

[1] OR and 95% CI are presented for a change of 1 standard deviation (4.2 years, 4.7 cm and 0.18 sec respectively)

[2] GrOS (Groin Outcome Score). OR and 95% CI are presented for a reduction of 10 in GrOS-score

Adjusted odds ratio (OR) and 95% confidence interval (CI) for the player dependent risk factors age and counter movement jump test (both calculated for a change of 1 standard deviation) and for the potential leg dependent risk factors previous acute groin injury, total GrOS (Groin Outcome Score) (calculated for a reduction of 10 in total score) and clinical examination for external rotation (painful or not), functional testing of the rectal abdominal muscles (painful or not), strength of adductor muscles (weak or not weak) and iliopsoas muscles (weak or not weak).

REFERENCES

1. Arnason A, Sigurdsson SB, Gudmundsson A, et. al.: Risk factors for injuries in football. *Am J Sports Med 32:* 5S-16S, 2004

2. Bahr R, Holme I: Risk factors for sports injuries--a methodological approach. *Br J Sports Med 37:* 384-392, 2003

3. Cowan SM, Schache AG, Brukner P, et. al.: Delayed onset of transversus abdominus in long-standing groin pain. *Med Sci Sports Exerc 36:* 2040-2045, 2004

4. Dvorak, J. and Junge, A. Football Medicine Manual - Pre-season medical assessment. 2005. Zurich, Switzerland: F-MARC. FIFA; 2005.

5. Ekstrand J, Gillquist J: The avoidability of soccer injuries. *Int J Sports Med 4:* 124-128, 1983

6. Emery, C. A. Does decreased muscle strength cause acute muscle strain injury in sport? A systematic review of the evidence. 4(3), 141-151. 1999. Phys Ther Rev.

7. Emery CA, Meeuwisse WH: Risk factors for groin injuries in hockey. *Med Sci Sports Exerc 33:* 1423-1433, 2001

8. Engebretsen AH, Myklebust G, Holme I, et. al.: Prevention of injuries among male soccer players: a prospective, randomized intervention study targeting players with previous injuries or reduced function. *Am J Sports Med 36:* 1052-1060, 2008

9. Engebretsen AH, Myklebust G, Holme I, et. al.: Intrinsic risk factors for acute ankle injuries among male soccer players: a prospective cohort study. *Scand J Med Sci Sports.* 2009 Jun 23. [Epub ahead of print]

10. Engebretsen, A. H., Myklebust, G., Holme, I., Engebretsen, L., and Bahr, R. Intrinsic risk factors for acute knee injuries among male soccer players – a prospective cohort study. *Scand J Med Sci Sports.* 2010 Mar 11. [Epub ahead of print].

11. Engebretsen, A. H., Myklebust, G., Holme, I., Engebretsen, L., and Bahr, R. Intrinsic risk factors for hamstring injuries among male soccer players – a prospective cohort study. *Am J Sports Med.* 2010 Mar 24. [Epub ahead of print].

12. Garrett WE, Jr., Safran MR, Seaber AV, et. al.: Biomechanical comparison of stimulated and nonstimulated skeletal muscle pulled to failure. *Am J Sports Med 15:* 448-454, 1987

13. Hagglund M, Walden M, Ekstrand J: Injury incidence and distribution in elite football--a prospective study of the Danish and the Swedish top divisions. *Scand J Med Sci Sports 15:* 21-28, 2005

14. Hagglund M, Walden M, Ekstrand J: Previous injury as a risk factor for injury in elite football: a prospective study over two consecutive seasons. *Br J Sports Med 40:* 767-772, 2006

15. Hagglund M, Walden M, Ekstrand J: Injuries among male and female elite football players. *Scand J Med Sci Sports* 2008

16. Hawkins RD, Fuller CW: A prospective epidemiological study of injuries in four English professional football clubs. *Br J Sports Med 33:* 196-203, 1999

17. Holmich P: Long-standing groin pain in sportspeople falls into three primary patterns, a "clinical entity" approach: a prospective study of 207 patients. *Br J Sports Med 41:* 247-252, 2007

18. Holmich P, Holmich LR, Bjerg AM: Clinical examination of athletes with groin pain: an intraobserver and interobserver reliability study. *Br J Sports Med 38:* 446-451, 2004

19. Holmich P, Uhrskou P, Ulnits L, et. al.: Effectiveness of active physical training as treatment for long-standing adductor-related groin pain in athletes: randomised trial. *Lancet 353:* 439-443, 1999

20. Inklaar H, Bol E, Schmikli SL, et. al.: Injuries in male soccer players: team risk analysis. *Int J Sports Med 17:* 229-234, 1996

21. Krause DA, Schlagel SJ, Stember BM, et. al.: Influence of lever arm and stabilization on measures of hip abduction and adduction torque obtained by hand-held dynamometry. *Arch Phys Med Rehabil 88:* 37-42, 2007

22. Leetun DT, Ireland ML, Willson JD, et. al.: Core stability measures as risk factors for lower extremity injury in athletes. *Med Sci Sports Exerc 36:* 926-934, 2004

23. Lian O, Engebretsen L, Ovrebo RV, et. al.: Characteristics of the leg extensors in male volleyball players with jumper's knee. *Am J Sports Med 24:* 380-385, 1996

24. Maffey L, Emery C: What are the risk factors for groin strain injury in sport? A systematic review of the literature. *Sports Med 37:* 881-894, 2007

25. Meeuwisse WH. Assessing causation in sport injury: A multifactorial model. Clin J Sport Med 4, 166-170. 1994.

26. Morelli V, Weaver V: Groin injuries and groin pain in athletes: part 1. *Prim Care 32:* 163-183, 2005

27. Orchard J, Wood T, Seward H, et. al.: Comparison of injuries in elite senior and junior Australian football. *J Sci Med Sport 1:* 83-88, 1998

28. Roos EM, Roos HP, Lohmander LS, et. al.: Knee Injury and Osteoarthritis Outcome Score (KOOS)--development of a self-administered outcome measure. *J Orthop Sports Phys Ther 28:* 88-96, 1998

29. Thacker SB, Gilchrist J, Stroup DF, et. al.: The impact of stretching on sports injury risk: a systematic review of the literature. *Med Sci Sports Exerc 36:* 371-378, 2004

30. Tyler TF, Nicholas SJ, Campbell RJ, et. al.: The effectiveness of a preseason exercise program to prevent adductor muscle strains in professional ice hockey players. *Am J Sports Med 30:* 680-683, 2002

31. Tyler TF, Nicholas SJ, Campbell RJ, et. al.: The association of hip strength and flexibility with the incidence of adductor muscle strains in professional ice hockey players. *Am J Sports Med 29:* 124-128, 2001

32. Walden M, Hagglund M, Ekstrand J: Injuries in Swedish elite football--a prospective study on injury definitions, risk for injury and injury pattern during 2001. *Scand J Med Sci Sports 15:* 118-125, 2005

33. Werner J, Hagglund M, Walden M, et. al.: UEFA injury study: a prospective study of hip and groin injuries in professional football over seven consecutive seasons. *Br J Sports Med 43:* 1036-1040, 2009

34. Witvrouw E, Danneels L, Asselman P, et. al.: Muscle flexibility as a risk factor for developing muscle injuries in male professional soccer players. A prospective study. *Am J Sports Med 31:* 41-46, 2003

Appendix

Regional komite for medisinsk forskningsetikk
Sør-Norge (REK Sør)

Dr. scient Grethe Myklebust
Senter for idrettskadeforskning
Norges idrettshøgskole
Postboks 4014 Ullevål Stadion
0806 Oslo

Deres ref.: 16.12.2003 **Vår ref.:** S-03231 **Dato:** 20.01.04

Forebygging av skader blant mannlige fotballspillere – en prospektiv randomisert intervensjonsstudie
Prosjektleder: Dr. scient. Grethe Myklebust, Senter for idrettsskadeforskning, Norges idrettshøgskole

Revidert informasjonsskriv

~~Vi takker for brev av 16.12.2003~~ vedlagt revidert informasjonsskriv. ~~Komiteen har ingen~~ merknader til informasjonsskrivet.

Komiteen har ikke mottatt orientering om hvordan rekrutteringen av utøverne er planlagt å skje, slik det er bedt om i komiteens vedtak, kfr. brev av 02.11.03. Komiteen tilrår likevel at prosjektet gjennomføres, men ber om at slik orientering ettersendes.

Vi ønsker lykke til med prosjektet.

Vennligst oppgi komiteens referansnr. ved korrespondanse om et prosjekt. Det bidrar til raskere saksbehandling.

På grunn av stor saksmengde har vi dessverre ikke kunnet svare så raskt som vi ønsker.

Med vennlig hilsen

Sigurd Nitter-Hauge (sign)
Professor dr.med.
Leder

Ola P. Hole
Avdelingsleder
Sekretær

Postboks 1130, Blindern, 0318 Oslo tlf 22 84 46 66 Faks 22 84 46 61
E-post: rek-2@medisin.uio.no, Besøksadresse: Frederik Holsts hus, Ullevål terrasse, Ullevål sykehus
http://www.etikkom.no/

"To myself I am only a child playing on the beach, while vast oceans of truth lie undiscovered before me"

Isaac Newton