Kathrin Steffen

Injuries in female youth football

Prevention, performance and risk factors

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Summary

Female football has experienced an enormous increase in popularity and in the number of active players worldwide. Previous research in female football has shown that the overall injury rate for female players is nearly as high as that for male players. As a consequence, effective injury prevention methods are needed for both genders at all age and skill levels. Especially for women, little is known about risk factors and mechanisms for injury which makes it difficult to develop injury prevention programs and to target these towards injury-prone athletes.

An exercise program, the "11", has recently been designed by FIFA Medical Assessment Research Center (F-MARC) to prevent the most common injury types in football; knee and ankle sprains, hamstring and groin strains. The "11" is a 15-min program consisting of ten exercises focusing on core stability, lower extremity strength, balance, agility, as well as a fair-play appeal, but its effect on injury risk is not known. If such training protocols are designed to not only prevent injuries, but to also increase player performance, this could potentially increase coach and athlete compliance. The main aim of this thesis was to assess the effect of the "11" on injury risk and on selected performance variables in young female football players. In addition, we wanted to examine some potential risk factors for injury: play on artificial turf, injury history and lower limb function, as well as psychological player characteristics.

Paper I: In the second half of the 2004 season, thirty-four young female football players (16-18 years) from two elite sport high schools were randomly assigned to either an intervention (n=18) or a control group (n=16). Performance tests before and after a 10-week intervention period with the "11" included isokinetic and isometric strength protocols for the quadriceps and hamstrings, isometric hip adduction and abduction strength, vertical jump tests, sprint running, and football skill tests. There was no difference between the intervention and control groups in the change of performance from the pre- to post-test for any of the variables tested. The most likely explanation is that the training volume and intensity for each of the exercises was too low to result in performance improvements. In addition, the test battery available may not have detected all potential improvements in performance.

Paper II: The purpose of this cluster-randomized controlled trial, conducted in the 2005 season, was to investigate the effect of the "11" on injury risk in 14- to 16-year old female football players. All participating teams were randomly assigned to either an intervention (n=59 teams, 1 091 players) or a control group (n=54 teams, 1 001 players). The intervention group was taught

the "11"-exercises to be used as a warm-up program for football training over an eight-month season. A total of 396 players (20%) sustained 483 injuries. No difference was observed in the overall injury rate between the intervention (3.6 injuries/1000 h, 95% CI 3.2 to 4.1) and the control groups (3.7, CI 3.2 to 4.1; rate ratio RR=0.99, CI 0.83 to 1.19; P=0.94) nor in the incidence for any injury type. During the first four months of the season, the training program was used during 60% of the football training sessions, but only 14 of 58 intervention teams completed more than 20 prevention training sessions. The compliance with the "11" was presumably insufficient to reduce injury rates in the intervention group.

Paper III: Artificial turf is becoming increasingly popular, although the injury risk on newer generations of turf is unknown. Based on data from the intervention study, we therefore investigated the risk of injury on artificial turf versus natural grass among young female football players. No difference was observed in the incidence of acute injuries on artificial turf compared to grass for match injuries (RR=1.05, CI 0.81 to 1.35, P=0.72) or training injuries (RR=0.98, CI 0.65 to 1.49, P=0.93). In matches, the incidence of serious injuries was higher on artificial turf (RR=1.98, CI 1.26 to 3.12, P=0.03). Ankle sprain was the most common injury type (34% of all acute injuries), and there was a trend towards more ankle sprains on artificial turf than on grass (RR=1.47, CI 0.98 to 2.20, P=0.06). The results indicated that the overall risk of acute injuries was similar between artificial turf and natural grass.

Paper IV: Since youth teams rarely are in direct contact with health care professionals, identifying players at increased injury risk through elaborate clinical tests is not feasible. We therefore wanted to examine whether injury history and lower limb function assessed by a self-administered questionnaire represent risk factors for injury. At baseline, all players enrolled in the intervention study were asked to complete a detailed questionnaire covering sports participation, history of previous injuries to the ankle, knee, hamstring or groin, as well as present function of these four specific regions. A total of 1 430 (71% of the participants in the intervention study) were followed up to record injuries during the subsequent season. History of a previous injury to the ankle (RR=1.18, CI 1.09 to 1.29, P<0.001), knee (RR=1.38, CI 1.22 to 1.57, P<0.001) or groin (RR=1.57, CI 1.16 to 2.12, P=0.004) increased the risk of new injuries to the same region. Reporting a reduced function (defined as <80% of the maximum score) for the ankle (RR=1.71 [1.09 to 2.70], P=0.021) and knee (RR=3.19 [1.80 to 5.68], P<0.001) were also significant risk factors. However, the sensitivity of the questionnaire in predicting new injuries was low and can therefore not be used to target injury prevention programs to athletes at risk.

Paper V: Successful performance in sports does not only require the athlete to be healthy and physically fit, but also mentally prepared to play. The influence of psychological factors on injuries in football is poorly documented. We therefore wanted to examine whether psychological player characteristics assessed by a self-administered questionnaire represent risk factors for injury. At baseline, the players in the intervention study were asked to complete a questionnaire covering perceptions of success and motivational climate, life stress, anxiety and coping strategies. There were significant differences to the disadvantage of previously injured compared to non-injured players for ego orientation ($P=0.007$), perception of performance climate ($P=0.003$) and experienced stressful life events ($P<0.001$). However, only high life stress ($P=0.001$) and perception of a mastery climate ($P=0.026$) were significant risk factors for new injuries.

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List of papers

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

I. Steffen K, Bakka HM, Myklebust G, Bahr R. Performance aspects of an injury prevention program: a 10-week intervention among adolescent female football players. *Scand J Med Sci Sports* 2008: 18(5): 596-604.

II. Steffen K, Myklebust G, Olsen OE, Holme I, Bahr R. Preventing injuries in female youth football - a cluster-randomized controlled trial. *Scand J Med Sci Sports* 2008: 18(5):605-614.

III. Steffen K, Andersen TE, Bahr R. Injury risk on artificial turf and natural grass among young female football players. *Br J Sports Med* 2007: 41 (Suppl 1): i33-i37.

IV. 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* 2008: 36(4): 700-708.

V. Steffen K, Pensgaard AM, Bahr R. Self-reported psychological characteristics as risk factors for injuries in female youth football. *Scand J Med Sci Sports*. Epub April 23.

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Introduction

History of female football

Football (soccer) is probably the most popular sport worldwide. With already more than 265 million players, interest is still growing with an increasing number of female players in particular (Norwegian Football Association, 2006; FIFA, 2007a).

In the beginning of the 20th century, football was exclusively played by men. Females were even banned from the sport in Europe by the European Football Association in 1921; the ban was finally lifted in 1971. The first European Championship for women was held in the period of 1982-1984 (UEFA, 2005) and the first World Cup in 1991 in China (FIFA, 2007b). Women's football has now established itself as a sport at the highest level. Worldwide, female football players account for 10% of all organized players (FIFA, 2007a).

Norway, a small country with 4.7 million inhabitants, has been strong in international women's football for much of the past two decades. A national elite league for female players was established in 1984; however, compared to male elite players, most female elite football players still have the status of amateurs or semi-professional players, with only a few full professionals.

Currently, in the Norwegian Football Association ("Norges Fotballforbund", NFF), over 100 000 female football players are registered, which accounts for about 25% of all players organized in the NFF (Norwegian Football Association, 2006). From 2001 to 2006, Norway experienced a 22% increase in the number of registered female football players, representing an annual increase of 6-10% among all females and 10-13% among 13- to 19-year olds. Similar tendencies are seen in other countries such as Germany (DFB, 2007), the US, Sweden, and in the countries belonging to the Confederation of North, Central American and Caribbean Association Football (CONCACAF) (FIFA, 2007a), illustrating the enormous increase in popularity of football for females.

Youth football

The competitive season for Norwegian youth football players lasts from the end of April until the mid of October with each team playing 14-24 league matches, including play-off games (final league play). For this age group, as in general, football has become an all-year sport with the pre-season period mostly from January to April. The competitive season is interrupted by a 6-7-week summer break without regular league matches. However, this break is often used for invitational tournaments.

When participating in 11-a-side football, a regular match is played for 2x45 min for 17- to 19-year old players and 2x40 min for players 15 and 16 years of age. Training sessions mostly last for 90-120 minutes, depending on level of play and the teams´ ambitions. In the northern climate, like in Scandinavia, it is often not possible to play football on natural grass for more than a few months a year, and artificial turf and gravel are the only other surface options, particularly in youth football.

Injuries in female football

Despite the growing number of participants in female football worldwide, relatively few studies have addressed the topic of injury in female football compared to male football.

This thesis will in the following sections provide a synthesis and critical review of the literature on injuries in female football, describing the epidemiology, risk factors and mechanisms leading to injuries. Completing this literature review will be the final step of the four-stage model of van Mechelen et al. (1992): the important issue of assessing the effectiveness of intervention programs to prevent injury (Figure 1).

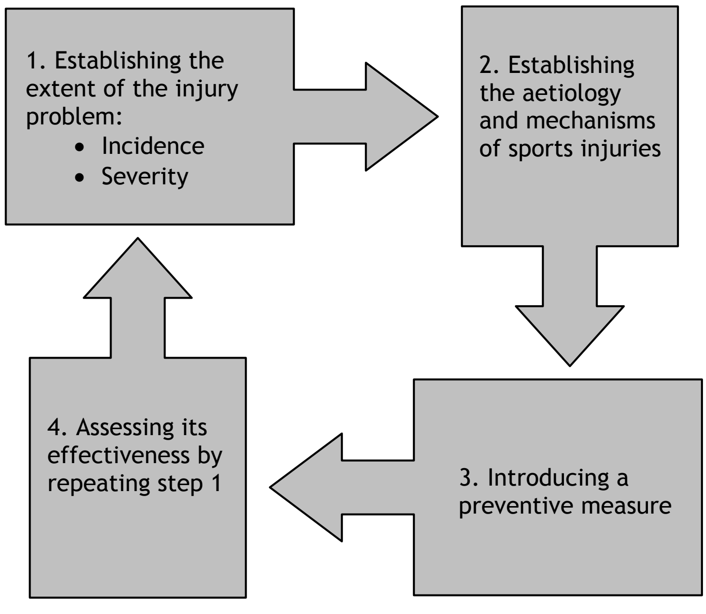

Figure 1: The four-stage sequence of injury prevention research (van Mechelen et al., 1992).

Definition of injury

Variations in definitions and methodologies used in injury epidemiology have contributed to differences in results and conclusions from published investigations. Therefore, some terms and definitions related to sports injury require clarification.

The National Athletic Injury Registration System (NAIRS) has defined a sports injury to be an injury which occurs as a result of participation in sports and which limits the athletic participation for at least one day after onset (van Mechelen et al., 1992).

A recent consensus statement on injury definitions and data collection procedures in football suggested that an injury is *"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"*. An injury that results in a player receiving medical attention is referred to as a *"medical attention"* injury, and an injury that causes the player to be unable to fully take part in match or training sessions the day following the injury is referred to as a *"time loss"* injury (Fuller et al., 2006).

In most epidemiological studies, regardless of sport, the time loss injury definition as used by NAIRS has commonly been used (Östenberg & Roos, 2000; Söderman et al., 2000, 2001a, 2001b; Myklebust et al., 2003; Faude et al., 2005; Hägglund et al., 2005b; Olsen et al., 2005; Waldén et al., 2005a; Ekstrand et al., 2006; Árnason et al., 2007; Jacobson & Tegner, 2007). However, in tournament football play, Junge et al. (2004b, 2006) and Junge & Dvorak (2007) have made use of a definition which defines an injury irregardless of the consequences with respect to absence from the match or training *("tissue"* injury definition). A few other studies in female football have limited injury recording to those injuries which were defined as requiring medical treatment (Schmidt-Olsen et al., 1985) or evaluated for insurance claims (Giza et al., 2005). The time loss and tissue injury definitions have been useful in comparing injury epidemiology within and between sports. However, researchers should be careful of certain limitations when applying these injury definitions.

When including time loss injuries only, accuracy in injury recording will depend on the frequency of training and match sessions in the particular study population. Minor injuries in particular can easily be missed in amateur and youth football when there is not play every day, and comparison to higher level play can be biased. Furthermore, easy access to health care, which is the expected standard at top, first and second division male football, but not necessarily in female and youth football, will also influence the decision as to whether a player will be ready or not to play the day following the injury. One other limitation of the time loss definition is its sports specificity, as shown by the example of a broken finger. This fracture will usually stop a team handball, basketball or volleyball player from sports participation, but not a football outfield player. The tissue injury definition on the other hand, allows all complaints to be recorded within the particular sport of interest and includes slight injuries which do not necessarily affect players´ health, for example pain, blisters, or skin abrasions. Since these injuries often do not stop the player from playing nor do they require further medical follow-up, high-quality injury recording relies on staff awareness in detecting every tissue injury.

Closely related to the issue of injury definition, is the classification of injury severity, necessary for comparison between studies. Severity can be described using the following criteria: nature and duration of injury, type of treatment, sporting time lost, working time lost, permanent damage, and costs (van Mechelen et al., 1992). The most frequently used classification systems for injury severity, independent of sport, are based on the number of days of absence from match or training. NAIRS classifies injuries as minor (1-7 days absence), moderate (8-21 days absence) or major (>21 days absence) (van Mechelen et al. 1992). According to the latest consensus discussions in FIFA (Federation of International Football Associations) and UEFA (Union of European Football Associations), injury severity is categorized in four categories, slight (1-3 days absence), minor (4-7 days absence), moderate (8-28 days absence) and major (>28 days absence) (Hägglund et al., 2005a; Fuller et al., 2006). This classification system is a further development from that of Ekstrand et al. (1983) which combined slight and minor injuries in one category, "minor", with 1-7 days absence from play. The later two injury classifications have primarily been used in investigations with elite players, in male (Árnason et al., 1996, 2004b, 2005, 2007; Hägglund et al., 2003, 2005b, 2006, 2007; Waldén et al., 2005a, 2006) and female football (Engström et al., 1991; Söderman et al., 2000; Faude et al., 2005; Jacobson & Tegner, 2006, 2007), although the exact number of days of absence varies slightly between studies. However, it is now strongly recommended, regardless of playing level, to follow the football consensus statement (Fuller et al., 2006) and split the first week (1-7 days absence) into "slight" and "minor".

The incidence of injury is usually expressed as the number of injuries per 1000 playing hours of exposure, with one exception. In many studies from North America, one athlete participating in one training session or match is defined as a unit of risk (Knapik et al., 1991; Arendt & Dick, 1995; Powell & Barber-Foss, 2000; Agel et al., 2005; Kucera et al., 2005; Dick et al., 2007), since this is the recording method established in the NCAA injury surveillance system. The duration in hours of one training session or match is not taken into consideration when calculating exposure. Consequently, studies presenting data as the number of injuries per 1000 player hours of exposure vs. per 1000 athlete exposures are not fully comparable.

Injury incidence in female football

During recent years, several injury surveillance studies have been published from female football, mostly from Sweden. Almost all studies have focused on elite players during seasonal or tournament play. Table 1 and Table 2 summarize the injury incidence from studies on adult and youth female football players participating in regular league play, as well as in tournament play at different levels.

Elite and amateur adult football

An early Swedish study, published in 1991 on 41 elite female players, presented injury rates as high as 24 and 7 per 1000 match and training hours, respectively (Engström et al., 1991). A recent 11-month prospective follow-up of female football players from the German National league system (241 injuries by 115 players) reported similar incidences of 23.8 and 2.8, respectively (Faude et al., 2005). Corresponding results were reported from 181 players, competing in the Norwegian female top league, sustaining 189 injuries during one season. This represents an incidence of acute injuries of 23.6 and 3.1 per 1000 match and training hours (Tegnander et al., 2007). Two more Swedish studies involving elite players, data collected from the 2000 (Jacobson & Tegner, 2007) and 2005 seasons (Hägglund, 2007), respectively, reported somewhat lower match injury rates (13.9 and 16.1). Similarly, retrospective insurance-based data from the first two seasons of the Women's United Soccer Association (WUSA) professional league showed the incidence of injuries during match and training to be 12.6 and 1.2 per 1000 hours (Giza et al., 2005). Their report corresponds to lower level football in Scandinavia. Three Swedish studies found injury incidences in amateur female players to range from 10.0 to 14.3 injuries per 1000 match hours, and 1.3 to 8.4 per 1000 training hours, respectively (Östenberg & Roos, 2000; Söderman et al., 2001b; Jacobson & Tegner, 2006). The overall injury rates in all these studies were comparable, regardless of playing level, and ranged between 4.6 and 9.6 injuries per 1000 playing hours except for one German study (Becker et al., 2006).

For elite male football players, match and training injury incidences have in most cases been reported to range between 22-35 and 2-6 injuries per 1000 match and training hours, respectively (Andersen et al., 2004b; Árnason et al., 1996, 2004b, 2005; Hägglund et al., 2003, 2005b; Waldén et al., 2005a, 2005b; Fuller et al., 2007a, 2007b; Hägglund, 2007). In other words, injury incidences for female elite players appear to be slightly lower than for male players. Based on two studies, simultaneously recording injuries for both genders (Fuller et al., 2007a, 2007b; Hägglund, 2007), female football players showed 57-88% of male match injury rates and 81-90% of male trainings injury rates.

Youth football

Only two cohort studies have been conducted so far in female youth football. Both studies were designed to follow their study populations prospectively over three (Emery et al., 2005) and seven months (Söderman et al., 2001a). Söderman et al. (2001a) found the overall injury rate of acute injuries among 14- to 19-year old Swedish females to be 4.4 per 1000 hours of play; 9.1 and 1.5 per 1000 match and training hours, respectively. Emery et al. (2005) included a wider age group with 12- to 18-year old Canadian female players showing similar injury rates in matches (8.9) and in training (2.6) to Söderman et al. (2001a).

However, compared to 14- to 18-year old male players who suffer an average of 10-16 match injuries per 1000 hours (Junge et al., 2004a; Le Gall et al., 2006), match injury rates of young female players are 13-44% lower.

Tournament football

Football has become an all-year sport with seasonal activities and tournaments of all playing levels. In three separate studies using identical injury recording systems, Junge et al. (2004b, 2006) and Junge & Dvorak (2007) reported data from the Women's World Cup 1999 and 2003, from the 2000 and 2004 Olympic Games, and from two U19 and one U20 World Championships. Taking all acute injuries into account, regardless of subsequent absence from play, incidences in World Cup matches were recorded as high as 39, and even higher in the Olympics, with 65-85 injuries per 1000 hours (24-49 expected time loss injuries per 1000 hours), respectively. Waldén et al. (2007) reported 36 time loss injuries per 1000 hours from the 2005 female European Championships. An injury registration during two years of the world's largest youth football tournament, Norway Cup, showed an overall injury incidence of 44 injuries per 1000 match hours (6 expected time loss injuries) for 13- to 19-year old girls (Soligard 2007, personal communication). This injury rate differs considerably from earlier studies in this (Maehlum et al., 1986) and other youth tournaments (Schmidt-Olsen et al., 1985; Backous et al., 1988), where 11-17 injuries per 1000 match hours had been recorded.

In summary, injury incidences in tournament matches seem to be higher in adult compared to youth female players. The average injury rates in top-level women's tournaments are comparable to match incidences reported for elite male players´ seasonal play, but are in general lower than in equivalent men's tournaments (Junge & Dvorak, 2007). This could not be confirmed by Waldén et al. (2007). In most youth tournaments, higher injury rates have been recorded in girls than for boys (Schmidt-Olsen et al., 1985; Maehlum et al., 1986; Backous et al., 1988).

Table 1. Prospective epidemiological studies on the incidence of injuries in adult female football.

Reference **Country, season, follow-up period**	**Population**	**No of all injuries**	**Injury recording**	**Injury definition**	**Injury incidence per 1000 h**		
					Match	Training	Total
Adults							
Tegnander et al. 2007 Norway, 2001, 7 months	Elite n=181 17-34 years	189	Physical therapists connected to the team, injury recording protocol	Time loss	23.6	3.1	
Jacobson & Tegner 2007 Sweden, 2000, 10 months	Elite n=269 16-36 years	237	Author in weekly contact to the teams, standardized injury protocol by phone	Time loss	13.9	2.7	4.6
Hägglund 2007 Sweden, 2005, 10 months	Elite n=228 15-41 years	299	Medical staff by standardized forms	Time loss	16.1	3.8	5.5
Becker et al. 2006 Germany, 2000-01, 11 months	Elite n=254 16-35 years	216	Author in weekly contact to a team assistant, injury recording protocol	Time loss			2.5
Jacobson & Tegner 2006 Sweden, 1998, 10 months	Amateur n=253 15-38 years	229	Author in weekly contact to the teams, standardized injury protocol by phone	Time loss	13.3	8.4	9.6
Faude et al. 2005 Germany, 2003-04, 11 months	Elite n=165 17-27 years	241	Medical staff (physical therapist, medical doctor), injury recording protocol	Time loss	23.3	2.8	6.8
Giza et al. 2005[1] USA, 2001-2003, 2 x 5 months	Elite n=202 Age unknown	173	Database of league insurance company	Conditions reported to and evaluated by the team physician	12.6	1.2	1.9
Söderman et al. 2001b[2] Sweden, 1998, 7 months	Amateur n=146 20-25 years	80	Players themselves in cooperation with coaches, diagnosis from physical therapists, injury protocol	Time loss	10.0 (acute)	1.3 (acute)	5.5 (acute)
Östenberg & Roos 2000 Sweden, 1996, 7 months	Amateur n=123 14-39 years	65	Physical therapist connected to the team, phone contact by the authors	Time loss	14.3	3.7	6.6
Engström et al. 1991 Sweden, season?, 12 months	Elite n=41 21 yrs	78	4 medical students	Time loss	24	7	

[1]Data were collected retrospectively. [2]Only acute lower extremity injuries were presented.

Table 2. Prospective epidemiological studies on the incidence of injuries in youth and tournament female football.

Reference **Country, season, follow-up period**	**Population**	**No of all injuries**	**Injury recording**	**Injury definition**	**Injury incidence per 1000 h**		
					Match	Training	Total
Youth							
Emery et al. 2005 Canada, 2004, 3 months	n=164 12-18 years	39	Medical staff (physical therapist/medical doctor), injury report form	Time loss	8.9	2.6	5.6
Söderman et al. 2001a Sweden, 1996, 7 months	n=153 14-19 years	79	Physical therapist by personal visits and phone contact in co-operation with the coaches, injury protocol	Time loss	9.1 (acute)	1.5 (acute)	4.4 (acute)
Tournament play							
Waldén et al. 2007 European Championship 2005 England, 2 weeks	Elite n=160 Age unknown	18	Team physician, standard injury card	Time loss	36.0	2.5	11.6
Junge et al. 2006 Olympic Games 2004 Athens, 2 weeks	Elite n=176[1] Age unknown	45	Team physician, injury report form	Tissue and time loss	70 (30 time loss)		
Junge et al. 2004 FIFA World Cup and Olympic Games 3 weeks (WC) and 2 weeks (OG)	Elite n=528 Age unknown	30 (WC) 32 (OG)	Team physician, injury report form	Tissue	38.7 (WC) 64.6 (OG) (24.2 time loss)		
Soligard 2007, personal communication Norway, 2005 and 2006, 1 week each	Youth n= ca. 7000 13-19 years	499	Coaches, tournament field hospital	Tissue	43.5 (5.7 time loss)		
Backous et al. 1988 USA, season?, 5 camps, 4½ days each	Youth n=458 6-17 years	107	Certified trainer, injury report form	Time loss	10.6		
Maehlum et al. 1986 Norway, 1984, 1 week	Youth n= ca. 3900 <19 years	145	Tournament medical staff	Unknown	17.6		
Schmidt-Olsen et al. 1985 Denmark, 1984, 1 week	Youth n=1325 9-19 years	117	Tournament medical staff	Injuries which require medical care with or without hospitalization	17.6		

[1]The player number was estimated from 22 players per team (16 teams in the WC and 8 teams in the OG); WC=FIFA World Cup 1999, OG=Olympic Games 2000.

Injury location and type in female football

On average, more than 80% of the injuries in female football affect the lower extremities and mainly involve the knee, foot/ankle and thigh. Furthermore, acute injuries represent 59-90% of injury types, while overuse injuries account for 10-41% (Table 3 and Table 4).

Elite and amateur adult football

In an injury recording as early as in the 1996 season, the most common injury type among amateur females was knee injuries (26%), followed by thigh (17%), foot (12%), and ankle injuries (11%) (Östenberg & Roos, 2000). Also in elite female football, Engström et al. (1991) registered the proportion of knee and ankle injuries to be 23% and 26%, respectively. Faude et al. (2005) reported four out of five injuries to be to the lower extremities; mainly to the knee (19%), ankle (18%) and thigh (18%). The injury pattern in the Women's United Soccer Association showed knee (32%) and head injuries (10%) to be the most commonly injured body parts (Giza et al., 2005). Three other investigations from female top level league play showed similar injury locations to these already listed (Becker et al., 2006; Hägglund, 2007; Tegnander et al., 2007). Similarly, a recently published study on 269 Swedish elite female players reported the knee (25%), thigh (19%) and ankle (13%) as the most typical injury locations, and strains (29%) and sprains (25%) as by far the most common injury types (Jacobson & Tegner, 2007). Interestingly, in amateur players, the same investigators recorded lower proportions of knee injuries and higher proportions of ankle injuries, and much fewer strain injuries (Jacobson & Tegner, 2006).

The most common injury types in elite female football, leading to absence from play are ligament sprains (19-47%), muscle strains (15-36%) and contusions (8-24%) (Engström et al., 1991; Faude et al., 2005; Giza et al., 2005; Becker et al., 2006; Hägglund, 2007; Jacobson & Tegner, 2007; Tegnander et al., 2007), and the same pattern was seen in amateur female players (Östenberg & Roos, 2000; Söderman et al., 2001b; Jacobson & Tegner, 2006).

Although the general injury rate is somewhat lower among female than male football players, the injury pattern seems to differ between genders. Knee and ankle injuries, typically as ligament sprains, are the most common injury locations in females. However, studies on elite male football players (Hawkins & Fuller, 1999; Hawkins et al., 2001; Árnason et al., 2004b; Waldén et al., 2005a, 2005b; Hägglund et al., 2005b) as well some recent investigations on elite female players (Jacobson & Tegner, 2007; Tegnander et al., 2007) have observed a shift from knee and ankle ligament injuries towards more thigh and groin strain injuries. The risk for hamstring or groin strain injuries has been shown to be 60% higher for elite male players compared to level-matched female players, while no gender-related difference in injury risk was seen for ligament injuries (Hagglund, 2007).

Youth football

Söderman et al. (2001a) found 89% of all recorded injuries to be located to the lower extremities. A total of 42% of injuries occurred in the knee or ankle. Similar to older female players, the most frequent injury types were ankle sprains (35%) and strains to the thigh musculature (25%). These data were confirmed by a second study on young female players; 79% were lower extremity injuries, with the ankle (28%) and knee (23%) most commonly affected (Emery et al., 2005). The top three injury types were ankle (26%), knee sprains (11%) and groin muscle strains (11%).

The present data suggest that young female football players demonstrate similar injury patterns to adult females. However, ankle sprain injuries represent the dominant injury type, and are proportionally more frequent among young than among elite female (Engström et al., 1991; Östenberg & Roos, 2000; Faude et al., 2005; Jacobson & Tegner, 2007) or male players (Árnason et al., 2004b; Waldén et al., 2005a; Hägglund, 2007). Compared to age-matched boys, it appears that young female players sustain fewer strain injuries and more ligament injuries (Junge et al., 2002, 2004a; Price et al., 2004; Le Gall et al., 2006). Groin strain injuries, in general, seem to be less common in female players (Söderman et al., 2001a; Emery et al., 2005; Faude et al., 2005) compared to male players (Árnason et al., 2004b; Hägglund et al., 2005b; Waldén et al., 2005a).

Tournament play

The injury patterns described in three publications by Junge et al. (2004b, 2006) and Junge & Dvorak (2007), including a total of seven major female tournaments, were different from seasonal play in reporting more head (16-27%) and lower leg injuries (9-20%), and a remarkably low proportion of knee injuries (7-16%). However, the data presentation included all injuries regardless of expected time loss. In contrast, four investigations from youth tournaments reported similar injury patterns as found in regular youth league matches (Schmidt-Olsen et al., 1985; Maehlum et al., 1986; Backous et al., 1988; Soligard 2007, personal communication).

Even though Waldén et al. (2007) recorded more strain injuries among male compared to female tournament players, the injury pattern in out-of-season competition appears to be quite similar between genders, regardless of playing level (Schmidt-Olsen et al., 1985; Maehlum et al., 1986; Backous et al., 1988; Junge et al., 2004b, 2006; Soligard 2007, personal communication).

Anterior cruciate ligament injuries

Team handball, basketball and football are all characterized by movement patterns which put an athletes´ knee in high-risk situations; e.g. by rapid accelerations and decelerations, sudden stops and changes in direction, and repetitive jumping and landing activities (Cowley et al., 2006). Female athletes are reported to have a 3-6 times higher incidence of anterior cruciate ligament (ACL) injuries than male athletes participating in the same pivoting sports (Hewett et al., 2006a; Griffin et al., 2006). The issue of ACL injuries in female football has therefore been the focus of several studies.

At the elite level, ACL injury rates were reported to range between 0.1 and 0.2 injuries per 1000 playing hours (Giza et al., 2005; Becker et al., 2006; Waldén, 2007) or between 0.6 and 2.2 injuries per 1000 match hours (Faude et al., 2005; Tegnander et al., 2007). Low-level adult players suffered 0.3 ACL injuries per 1000 hours (Östenberg & Roos, 2000; Fuller et al., 2007a, 2007b). However, compared to top-level female team handball (2.7 ACL injuries per 1000 hours in the control season) (Myklebust et al., 2003), the ACL injury rate in female football is considerably lower. Among 14- to 18-year old females, Mandelbaum et al. (2005) recorded an ACL injury rate of 0.5 per 1000 athletes exposure. Rates reported for 15- to 18- (Bjordal et al., 1997) and 17- to 22-year old female players (Arendt & Dick, 1995; Agel et al., 2005) were slightly lower; 0.1-0.3 per 1000 playing hours and athlete exposures, respectively.

Evidence for gender-related differences in ACL injury risk in football is now available from two prospective studies which followed Swedish (Waldén, 2007) and US college football players (Fuller et al., 2007a, 2007b). While no gender-related differences in the incidence of ACL injuries were seen among Swedish players (RR=0.99, 95% CI 0.4-2.6), Fuller et al. (2007a, 2007b) found a more than 3-fold injury risk for female compared to male players (1.45 versus 0.45 ACL injuries per 1000 match hours). Based on retrospectively collected data from youth football, the risk of an ACL injury in junior football (15-18 years) has been estimated to be up to five times higher for girls than for boys (Bjordal et al., 1997), and between 2.4-2.8 higher for female college football players compared to their male counterparts (Arendt & Dick, 1995; Powell & Barber-Foss, 2000; Agel et al., 2005). Women have been observed to injure their knees at an earlier age than men (Arendt & Dick, 1995; Roos et al., 1995; Bjordal et al., 1997; Shea et al., 2004). However, based on somewhat inconsistent findings of the ACL injury risk for females in the age group 15 to 20 years, it is difficult to evaluate the exact age at which the risk for ACL injuries increases. Theories about the effects of gender and puberty on neuromuscular performance suggest that the critical period may be around the age of 16 years (Hewett et al., 2006b).

Table 3. All injury locations and injury types in prospective studies on adult female football players (%).

Reference	**Engström 1991**	**Östenberg & Roos 2000**	**Söderman 2001b[1]**	**Giza 2005[2]**	**Faude 2005**	**Jacobson & Tegner 2006**	**Becker 2006**	**Hägglund 2007**	**Jacobson & Tegner 2007**	**Tegnander 2007**
Season	Unknown	1996	1998	2001-03	2003-04	1998	2000-01	2005	2000	2001
Follow-up	12 months	7 months	7 months	2 x 5 months	11 months	10 months	11 months	10 months	10 months	7 months
Players	41	123	146	202	165	253	254	228	269	181
Level of play	Elite	Amateur	Amateur	Elite	Elite	Amateur	Elite	Elite	Elite	Elite
Injuries	78	65	80	173	241	229	216	299	237	189
Age range (years)	21 (mean)	14-39	21 (mean)	Unknown	17-27	15-38	16-35	15-41	16-36	17-34
Injury location										
Head/neck	-	-	-	10.4	6.6	4.7	7.0	4.9	5.9	7.4
Shoulder/arm/finger	-	-	-	7.5	5.3	0.4	11.0	2.0	1.7	4.8
Trunk/back	3.8	10.8	-	12.8	7.5	12.7	-	9.0	10.5	6.9
Hip	-	-	-	5.5	0.8	4.8	2.0	11.4	7.2	9.0
Groin	6.4	7.7	3.3		5.4		-			
Thigh	15.4	17.0	16.4	6.9	18.3	11.4	15.0	23.1	19.4	17.5
Knee	23.0	26.2	24.6	31.8	18.7	15.3	27.0	22.1	24.9	16.4
Lower leg	9.0	6.2	4.9	6.5	8.2	12.2	9.0	7.0	10.5	7.4
Ankle	25.6	10.8	45.9	9.3	17.8	28.4	23.0	16.1	13.1	23.8
Foot	9.0	12.3	4.9	9.3	11.2	10.5	6.0	5.4	6.8	6.9
Other	7.7	9.2	-	-	-	-	-	-	-	-
Injury type										
Sprain	33.3	18.5	65.6	19.1	46.5	28.4	31.0	26.8	24.5	31.2
Strain	10.3	32.2	16.4	30.7	17.4	6.7	15.0	34.1	28.7	36.0
Contusion	15.3	16.9	18.0	16.2	23.7	18.3	16.0	13.4	8.4	7.4
Fracture	1.2	3.1	-	11.6	5.4	2.2	-	4.1	1.3	5.3
Concussion	-	-	-	2.9	-	3.1	-	2.4	3.8	-
Dislocation	-	-	-	-	-	-	-	1.2	0.8	-
Other	15.3	7.8	-	-	16.1	0.4	18.0	15.1	1.7	9.0
Overuse	28.2	21.5	23.8	16.2	16.2	41.1	19.0	17.7	31.2	10.1

[1]Only acute lower extremity injuries were presented. [2]Data were collected retrospectively.

Table 4. All injury locations and injury types in prospective studies on youth female football and tournament players (%).

Reference	**Söderman 2001a**	**Emery 2005[1]**	**Schmidt-Olsen 1985**	**Maehlum 1986**	**Backous 1988**	**Junge & Dvorak 2007**	**Junge 2004b**	**Junge 2004b**	**Junge 2006**	**Soligard 2007[2]**	**Waldén 2007**
Season	1996	2004	1984	1984	Unknown	1999-2006	1999	2000	2004	2005-2006	2005
Follow-up	7 months	3 months	1 week	1 week	4½ weeks	15 weeks	3 weeks	2 weeks	2 weeks	2 weeks	2 weeks
Players	153	164	1325	3900	458	Unknown	352	176	176	7000	160
Level of play	Youth	Youth	Youth	Youth	Youth	Elite	Elite	Elite	Elite	Youth	Elite
Injuries	79	47	117	145	197	387	30	32	45	499	18
Age range (years)	14-19	12-18	9-19	<19	6-17	Unknown	Unknown	Unknown	Unknown	13-19	Unknown
Injury location											
Head/neck	-	10.6	5.1	-	6.5	17.3	33.0	25.0	16.0	15.2	5.6
Shoulder/arm/finger	3.8	6.4	6.8	-	3.7	8.3	4.0	9.0	7.0	6.0	5.6
Trunk/back	1.9	4.3	5.1	-	3.7	8.5	4.0	3.0	9.0	8.5	-
Hip	-	10.6	-	-	1.3	3.1	-	-	2.0	2.3	-
Groin	1.9	-	2.6	-	5.1		-	-		0.2	-
Thigh	26.9	6.4	12.8	-	19.0	12.1	8.0	22.0	16.0	10.9	16.7
Knee	15.4	23.4	8.5	-	19.0	11.1	8.0	-	11.0	11.7	22.2
Lower leg	5.8	2.1	6.0	-	12.7	10.6	25.0	9.0	13.0	9.1	22.2
Ankle	34.6	27.7	22.2	-	22.8	24.0	17.0	22.0	20.0	24.1	16.7
Foot	9.6	8.5	30.8	-	8.9	3.1	-	-	7.0	11.3	11.1
Other	-	-	-	-	2.5	1.8	-	9.4	-	-	-
Injury type											
Sprain	48.1	36.1	21.3	25.5	21.4	24.5	15.0	13.0	29.0	11.7	16.7
Strain	28.8	19.1	8.5	-	23.4	8.0	12.0	25.0	9.0	14.8	11.1
Contusion	11.5	-	31.6	45.5	30.8	42.6	35.0	44.0	36.0	59.3	50.0
Fracture	3.8	-	3.4	6.2	-	2.3	8.0	-	2.0	0.6	11.1
Concussion	-	4.3	0.9	-	-	3.1	-	6.0	4.0	-	5.6
Dislocation	3.8	-	0.9	-	-	2.1	3.0	-	4.0	0.9	-
Other	3.8	40.4	28.2	22.8	22.8	17.3	27.0	12.0	16.0	11.1	-
Overuse	34.2	-	6.0	-	-	0.8	-	-	-	1.5	-

[1]Only acute injuries were presented. [2]Personal communication.

Injury severity in female football

Based on detailed data from 14 studies which present injury severity in terms of *"days of absence from football"*, the majority of injuries in female football tend to be minor (<1 week) or moderate (Table 5). No major difference is observed between adult, youth and tournament play, although there might be a tendency towards more mild injuries among elite players compared to amateur or youth players whose teams usually are not in direct contact with a health care system.

Table 5. Severity of injuries according to the number of days absent from play (days shown in parentheses). Percent values were calculated in relation to all injuries.

Reference	**Population**	**Severity classification**			
		Minor		Moderate	Major
		(1-6)		(7-30)	(>30)
Faude et al. 2005	Elite	51		36	13
Engström et al. 1991	Elite	49		36	15
Söderman et al. 2001b[1]	Amateur	34		49	18
Östenberg & Roos 2000	Amateur	31		51	18
Söderman et al. 2001a	Youth	34		52	14
		(1-7)		(8-21)	(>21)
Tegnander et al. 2007	Elite	51		28	21
		(1-7)		(8-36)	(>36)
Becker et al. 2006	Elite	34		39	27
		(1-3)	(4-7)	(8-28)	(>28)
Jacobson & Tegner 2007	Elite	17	22	39	22
Hägglund 2007	Elite	25	28	34	12
Jacobson & Tegner 2006	Amateur	13	39	37	11
		(1-3)	(4-7)	(8-28)	(>28)
Waldén et al. 2007	Elite	53	0	27	20
		(1-3)	(4-7)	(8-30)	(>30)
Junge et al. 2006[2]	Elite (OG 2004)	53	26	16	5
Junge et al. 2004b[2]	Elite (WC 1999+OG 2000)	50	17	33	-
		(0-1)	(2-7)	(8-14)	(>14)
Emery et al. 2005[3]	Youth	36	36	8	21

[1]Only acute lower extremity injuries were presented. [2]Severity was estimated based on the anticipated duration of absence from football. [3]Only acute injuries were presented.
WC=FIFA World Cup, OG=Olympic Games

Injury risk factors

Researchers have used different approaches to identify risk factors for sport specific injuries. However, risk factors must be clearly established before intervention programs can be targeted towards injury-prone athletes (Bahr & Holme, 2003; Murphy et al., 2003; Emery, 2005).

Meeuwisse's model of multifactorial etiology for athletic injury

Injury causation is usually complex. Models have therefore been developed in order to describe multicausal connections, which also take into account the chain of events that leads to an injury (Figure 2).

Traditionally, risk factors are divided into two main categories: intrinsic athlete related factors and extrinsic environmental risk factors (van Mechelen et al., 1992). Meeuwisse's multifactorial model (Meeuwisse, 1994) classifies intrinsic risk factors as predisposing factors that may be necessary, but seldom sufficient, to provoke an injury. The presence of one or more intrinsic risk factors may contribute towards athlete susceptibility to injuries. Both intrinsic and extrinsic risk factors are usually distant from the time of the injury and are rarely sufficient to be the lone cause of the injury. It is the sum of, as well as the interactions between, these factors, together with the inciting event (injury mechanism), that causes the athlete to be injured (Bahr & Holme, 2003; Bahr & Krosshaug, 2005).

Causes of injury

Risk factors, whether intrinsic or extrinsic, are either modifiable or nonmodifiable. Nonmodifiable factors can not be altered, but may still affect the relationship between modifiable risk factors and injury (Meeuwisse, 1991). They can also be used to target intervention programs towards individuals at greater risk, for example females in the case of ACL injuries. However, for future intervention studies, modifiable risk factors will be even more important to identify, since these can be influenced (Emery, 2005). 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).

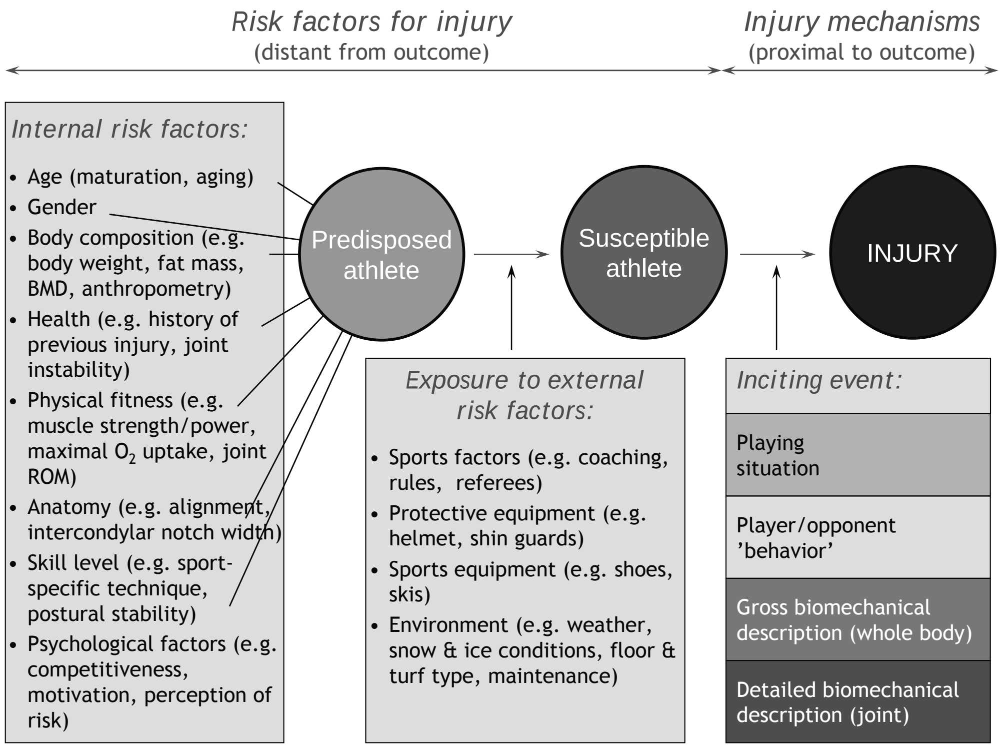

Figure 2. Comprehensive model for injury causation. Complex interaction between intrinsic and extrinsic risk factors leading to an inciting event and resulting in injury (Meeuwisse, 1994, modified by Bahr &Krosshaug, 2005).

The following section is restricted to risk factors related to the most common lower extremity injuries in female football as outlined in the epidemiology section: ankle and knee sprains, hamstring and groin strains. A summary of nonmodifiable and modifiable risk factors is given in Table 6. However, considering the historical development of female football throughout the past years, few studies have been performed on injury risk in female compared to male football.

Nonmodifiable risk factors

Previous injury

Inadequate rehabilitation and a history of previous injuries have been suggested by many to be a risk factor for injuries in football (Tropp et al., 1985; Surve et al., 1994; Árnason et al., 2004b; Hägglund et al., 2006). Initiated by high rates of recurrent injuries among male (22-42%) (Hawkins & Fuller, 1999; Árnason et al., 2004b; Hägglund et al., 2006; Waldén et al., 2006) and female players (19-46%) (Östenberg & Roos, 2000; Söderman et al., 2001b; Faude et al., 2005, 2006; Jacobson & Tegner, 2006, 2007), previous injury as a risk factor has been analyzed in several investigations.

In male football, an injury history has been identified as an injury risk factor for ankle sprains (Ekstrand et al., 1983; Tropp et al., 1985; Surve et al., 1994; Árnason et al., 2004b; Kofotolis et al., 2007) and knee sprains (Árnason et al., 2004b; Hägglund et al., 2006; Waldén et al., 2006), as well as for groin and hamstring strains or injuries, respectively (Árnason et al., 2004b; Hägglund et al., 2006). A previous knee injury has also been strongly associated with new injuries in a cohort of young male and female players treated as one group (Kucera et al., 2005). However, two studies from elite male (Hägglund et al., 2006) and female football (Faude et al., 2006) did not find a relationship between previous ankle sprains and new injuries to the same side of the foot. Neither were Söderman et al. (2001b), studying female amateur players, able to identify an association between previous injuries during a period of three months before the start of the study and new injuries in the follow-up period. In conclusion, scientific evidence regarding re-injury risk in female football is insufficient, especially among younger players. Previous lower limb injuries as a risk factor for new injuries were therefore the focus of Paper IV.

Age

Higher rates of injuries have been documented among adult compared to young players, while there is more uncertainty about age as a risk factor within the group of adult players. Older age was identified to be a significant risk factor for injuries in male football players above the age of 28 years (Árnason et al., 2004b), in female players above the age of 25 years (Östenberg & Roos, 2000) and among youth players (Kucera et al., 2005). In contrast, Emery et al. (2005) observed a greater risk of injury in the youngest age group (U14 vs U18). Possibly biased by the age groups used for the analysis, no association was found between injury risk and older age in other studies on female players (Söderman et al., 2001b; Faude et al., 2006).

Gender

In regular league play, injury rates were reported to be higher for male compared to age-and level-matched female football players. In tournament play, some researchers found a higher injury rate for male players (Junge & Dvorak, 2007) or female players (Schmidt-Olsen et al., 1985; Maehlum et al., 1986; Backous et al., 1988), while others did not (Junge et al., 2006; Waldén et al., 2007; Soligard 2007, personal communication). Gender-related injury differences have also been observed for certain types of injuries. Hamstring and groin strain injuries appear to be more predominant in male than in female football (Árnason et al., 2004b, 2007; Hägglund et al., 2005b; Hagglund, 2007). In youth football, more strain injuries have been recorded for boys (Junge et al., 2004a; Price et al., 2004; Le Gall et al., 2006) than for girls where ligament injuries seem to be predominant (Söderman et al., 2001a; Emery et al., 2005). Investigations by Bjordal et al. (1997), Powell & Barber-Foss (2000), Agel et al. (2005), Olsen et al. (2005) and Fuller et al. (2007a, 2007b) all found female gender to be closely related to an increased ACL injury risk. However, these findings could not be confirmed by a recently conducted study (Waldén, 2007). Thus, while there is clear evidence of a somewhat lower overall injury rate among female compared to male players, females tend to have more ligament but fewer muscle injuries than males.

Alignment of the lower limb

Anatomical alignment of the lower limbs has been discussed as a potential injury risk factor. Increased Q-angle, a wider pelvis, intercondylar notch size and an increased genu valgus have all been proposed as contributing factors for knee injuries by altering lower limb kinematics (Mizuno et al., 2001; Griffin et al., 2006). However, a clear consensus is still missing (Griffin et al., 2006). In the only study on female football designed to analyze risk of malalignment for lower extremity injuries, Söderman et al. (2001b) did not find Q-angle, knee or foot alignment to be a significant risk factor.

Sex hormones

The influence of sex hormones has mostly been linked to ACL injuries, and there appears to be a relationship between hormonal fluctuations across the menstrual cycle and anterior knee laxity, which may influence ACL injury risk (Shultz et al., 2005). However, the epidemiological evidence for this relationship is contradictory. Assessments of this relationship have shown athletes to be more susceptible to injury in both the menstrual phase (day 1-7 of the menstrual cycle) (Myklebust et al., 1998; Slauterbeck et al., 2002) and the ovulation phase (Wojtys et al., 2002). Møller-Nielsen & Hammar (1989) and Jacobson (2006) found higher rates of acute injuries in general during the premenstrual and menstrual phases compared to the rest of the menstrual cycle. These two studies (Møller-Nielsen & Hammer, 1989; Jacobson, 2006) are the only studies that have examined this relationship among female football players. Thus, there is no conclusive evidence associating an increase in injuries to a specific period within the menstrual cycle.

Body size

Body size can be defined as both nonmodifiable (height) and modifiable (weight). Studies on male football players (Árnason et al., 2004b; Hägglund et al., 2006) and one study including both male and female players (Kucera et al., 2005) did not find an association between injury risk and anthropometrics. Only three studies on female football players have assessed body size in a risk factor analysis. Using a multivariate approach, Östenberg & Roos (2000) and Kucera et al. (2005) did not find BMI (body mass index) to be a risk factor for the overall injury rate. Backous et al. (1988) reported an increased injury risk for boys taller than 165 cm, but not for girls. In an analysis by Faude et al. (2006), taller adult female players (≥175 cm), regardless of weight, were at higher injury risk. Body size (height, weight, BMI) as an intrinsic predisposing injury risk factor was examined in Paper IV.

Level of play and level of competition

There is general agreement that injuries occur more often in competition and in elite level play than in training sessions and lower level play, without regard to age or gender. These relationships between level of play and injury risk have been outlined in detail in the section on injury incidence.

Playing surface

Artificial turf has become a popular alternative playing surface in football worldwide. Compared to team handball, where more injuries have been seen on high-friction artificial floor compared to wooden floor (Olsen et al., 2003), injury risk on artificial turf is poorly documented for football. Studies conducted on first generation artificial turfs indicated that injury risk was higher on these turfs compared to natural grass among males (Engebretsen & Kase, 1987; Árnason et al., 1996). Two recent studies, represented by three papers, included the first data collected on second and third generation artificial turf and show similar overall injury rates on turf as on natural grass among elite male (Ekstrand et al., 2006), college male (Fuller et al., 2007a, 2007b) and college female players (Fuller et al., 2007a, 2007b). Data on injury risk for young females playing on artificial turf are lacking, and this question was therefore addressed in Paper III.

Time in match/time in season

Possibly reflecting fatigue, a significantly higher proportion of non-contact injuries was observed in the second half of tournament games for both female and male players (Waldén et al., 2007). Research among Icelandic male players, however did not support time in matches to be a risk factor (Árnason et al., 2004b). In female World Cup tournaments, there was no difference between group and knock-out matches, but in knock-out matches, injury risk increased by 2.5 times during the last 15 min of the second half of the match compared with any other time in the match (Tscholl et al., 2007a). Studies on male (Hawkins et al., 2001; Ekstrand et al., 2004) and on female football players (Jacobson & Tegner, 2006) have shown that both acute and overuse injuries mainly occurred in the pre-season or early competitive season. In conclusion, the issue of injury time during matches is controversial, and the evidence is poor.

Years/hours of exposure

Exposure can be defined as both nonmodifiable (playing years) and modifiable (weekly hours). In female amateur football, Söderman et al. (2001b) found more hours of weekly exposure to football play to be a positive injury risk factor. Östenberg & Roos (2000) did not find this association for an increased number of years of exposure. In addition, more match exposure throughout the season has been identified to be a negative injury risk factor in elite female football (Faude et al., 2006). There is not much data on injury risk from playing exposure, in general and no data are available on young female players. To address this issue, weekly sports participation and the total number of years of play in organized football have been included in the risk factor analyses in Papers IV and V.

Modifiable risk factors

Muscle strength and muscle imbalance

Low muscular strength has been observed to be a risk factor for hamstring strains in male football (Askling et al., 2003). In female amateur football, Söderman et al. (2001b) found a lower hamstrings/quadriceps ratio (H/Q ratio) during concentric strength testing at $90°\cdot s^{-1}$ to be related to a higher risk for acute lower extremity injuries. This is in accordance with findings from Knapik et al. (1991), who in 138 female college athletes, including football players, observed that an H/Q ratio less than 75%, measured at $180°\cdot s^{-1}$, was a risk factor for a higher overall injury risk. There was also a trend towards a higher injury rate being associated with a hamstring strength imbalance of 15% or more compared to the opposite side of the body. In female amateur players, Östenberg & Roos (2000) found that isokinetic muscle torques for the quadriceps and hamstring were not associated with football injuries, but they had not reported H/Q ratios.

In conclusion, while there is no clear scientific evidence, there is a trend towards an association between strength and injury risk among female football players. Nevertheless, there is evidence to support the hypothesis that eccentric hamstring strength may be an important protective factor for hamstring strains in male players (Askling et al., 2003; Árnason et al., 2007). Further studies are needed to investigate the relationship between strength and injury in female football players. Strength is a modifiable factor and may easily be part of injury intervention and general training programs. As an example, eccentric hamstring training has now been included as an essential part of successful injury prevention programs in football and team handball (Hewett et al., 1999; Mandelbaum et al., 2005; Olsen et al., 2005; Árnason et al., 2007).

Joint laxity and range of motion

There are studies on male football players indicating that general joint laxity, mechanical and functional instability may be factors predisposing for ankle injuries (Tropp et al., 1985; Surve et al., 1994; Árnason et al., 1996). In female amateur football, Söderman et al. (2001b) found players with generalized joint laxity to be at increased risk. When hyperextension of the knee joint was studied separately, it was also found to be a significant risk factor. These results were confirmed by another study on female players, applying the same measurements (Östenberg & Roos, 2000).

Material and functional changes following repetitive disruptions of the afferent-efferent information from and to the ankle joint are proposed to increase the risk of repetitive ankle sprains (Beynnon et al., 2002; Docherty et al., 2006). However, in contrast to male football, none of the studies in female football were able to find a significant association between decreased range of motion or increased joint laxity and ankle injuries (Östenberg & Roos, 2000; Söderman et al., 2001b) or between decreased range of motion and lower extremity strain and sprain injuries (Jacobson, 2006). It might be that reduced ligament or muscular function are not risk factors in female football, but the few studies published to date do not provide sufficient data from which to draw a firm conclusion. The potential of a questionnaire aimed at relating reduced lower limb function to injury risk was the focus of Paper IV.

Neuromuscular control

Studies from different sports have shown that female athletes tend to land more often with their knees in a valgus position compared to males (Krosshaug et al., 2007; Pollard et al., 2007). Furthermore, they are prone to do side step cutting and landing activities with less knee and hip flexion than males do (Ford et al., 2005; Krosshaug et al., 2007; Pollard et al., 2007).

In female football, only three studies have analyzed static and dynamic balance in relation to injury risk (Östenberg & Roos, 2000; Söderman et al., 2001b; Emery et al., 2005). Surprisingly, Söderman et al. (2001b) measured low postural sway (equal to good balance) in injured players. Östenberg & Roos (2000) identified a high performance in functional single-leg tests (more than 25 square hops in 30 s) to be significantly predictable for injury risk. Emery et al. (2005) did not find any association between dynamic balance and an increased injury risk.

Despite these unexpected findings from female football, neuromuscular training concepts aimed at avoiding excessive knee valgus motions have been introduced in different athlete populations and with promising results, especially on ACL injuries (Caraffa et al., 1996; Hewett et al., 1999; Myklebust et al., 2003; Wedderkopp et al., 2003; Myer et al., 2005; Mandelbaum et al., 2005; Olsen et al., 2005). The effect of an injury prevention program, including neuromuscular exercises as one component, was assessed in Paper II.

Psychological factors

Psychosocial stressors, coping resources, and situation-dependent emotional states appear to have an effect on an athlete's risk for a sports injury (Williams & Andersen, 1989; Junge, 2000; Johnson et al., 2005; Schwebel et al., 2007). Male players with a more than average number of previous injuries were more worried about their performance, perceived more peaking under pressure, and had more outward anger expression and competitive anxiety (Junge et al., 2000). Swedish elite female and male football players with high levels of life stress and low coping strategies were more injury-prone than players with lower stress levels (Johnson et al., 2005). Except for one study on 11- to 12-year old boys (Schwebel et al., 2007) which did not find aggression or risk-taking behavior to be injury risk factors, there is no prospective evidence available concerning the relationship between player personality traits and injury risk in youth football. In Paper V, we therefore examined whether individual player characteristics can be identified as risk factors for new injuries in young female players.

Physical fitness

Explosive efforts during sprints, duels, jumps, and kicks are important performance factors in football, requiring maximal strength and anaerobic power of the neuromuscular system (Wisløff et al., 1998; Cometti et al., 2001; Reilly & Gilbourne, 2003; Hoff & Helgerud, 2004). Low physical fitness may therefore contribute to an increased injury risk. In preventing injuries, increased strength has been shown beneficial in male (Askling et al., 2003; Árnason et al., 2007) and female athletes (Knapik et al., 1991; Östenberg & Roos, 2000; Söderman et al., 2001b). However, jumping height among young females (Emery et al., 2005) and estimated VO_{2max} (maximum oxygen uptake) among female (Östenberg & Roos, 2000; Emery et al., 2005) and male football players (Árnason et al., 2004a) could not be associated to injury risk. To conclude, there is little knowledge about the potential relationship between physical fitness and injury risk.

Equipment

The protective effect of ankle bracing and taping has been shown in male football (Ekstrand et al., 1983; Tropp et al., 1985; Surve et al., 1994), and retrospectively also in female football (Sharpe et al., 1997), although only for players with previous ankle injuries. There is no prospective study in female football assessing the effect of protective equipment and it is not clear whether the results of ankle bracing and taping can be transferred to female players.

Summary

To sum up the literature on modifiable and non-modifiable risk factors for injuries in female football, there are few prospective cohort studies on females in general and contradicting results regarding the most commonly proposed risk factors. This may partly be ascribed to small sample and effect sizes or inaccurate measurement tools (Bahr & Holme, 2003; Murphy et al., 2003). Well designed prospective cohort studies, including sufficient sample sizes and a focus on assessing potential injury risk factors in youth female football, are lacking.

Reviewing the literature on risk factor studies also indicates that there are hardly any studies in football that have made use of multifactorial approaches. So far, only two prospective cohort studies investigated a multivariate model to analyze risk factors for injuries in female football (Östenberg & Roos, 2000; Söderman et al., 2001b). In addition, one study on young female and male players used a multivariate approach both on retrospective and prospective data (Kucera et al., 2005).

In many studies on adult players, previous injury has been shown to be a significant risk factor for a future injury, possibly through physiologic or anatomic deficits resulting from the previous injury, e.g. reduced strength and neuromuscular control or increased joint laxity. The case of a previous injury illustrates how modifiable risk factors, such as reduced strength, range of motion or neuromuscular control, can influence the non-modifiable risk factor to reduce re-injury risk.

Table 6. Prospective studies on risk factors for injuries in female football using adequate statistical methods to test the effect of potential risk factors.

	Backous 1988	**Östenberg & Roos 2000**	**Söderman 2001b**	**Emery 2005**	**Johnson 2005**	**Kucera 2005**	**Faude 2006**	**Jacobson 2006**	**Fuller 2007a, 2007b**	**Tscholl 2007a**
Follow-up period	1 week	7 months	7 months	3 months	4 months	3½ years	11 months	10 months	2 x 5 months	2 weeks
Gender	F+M	F	F	F	F+M	F+M	F	F	F	F
Players	458	123	146	164	32	1483	143	455	Unknown	Unknown
Injuries	107	65	80	39	24	905	216	193	1720	233
Level of play	Youth	Amateur	Amateur	Youth	Elite	Youth	Elite	Elite+amat	College	Elite
Statistics	χ^2	Multi Log regression	Multi Log regression	χ^2	Mann-Whitney U	Multi Poisson regression	χ^2	χ^2	χ^2	χ^2
Nonmodifiable risk factors										
Previous injury			No			Pos	No			
Older age		Pos	No	Neg		Pos	No			
Female gender									Pos (ACL)	
Increased Q-angle			No							
Body size										
Greater height	No						Pos			
Greater weight							No			
Greater BMI		No				No			No	
Artificial turf										
Time of injury/season										Pos
Exposure										
More match exposure							Neg			
More weekly hours			Yes							
More playing years		No								
Modifiable risk factors										
Low strength		No	Pos							
General joint laxity		Pos	Pos							
Reduced range of motion		No	No					No		
Reduced neuromuscular control		Neg	Neg	No						
High levels of stress					Pos					
Physical fitness										
Low VO_{2max}		No		No						
Low jumping height				No						

Abbreviations: Pos=positive association, No=no association, Neg=negative association, respectively, between risk factor and injury risk; F=female, M=male; Multi=multivariate; Log=logistic

Injury mechanisms

In female football especially, many questions about potential injury risk factors and their causal relationships remained unanswered. Furthermore, establishing risk factors for injuries in football is not sufficient alone. The development of injury prevention programs requires an identification of the mechanisms by which the injury occurs (Bahr & Krosshaug, 2005).

According to Bahr & Krosshaug (2005), a complete description of the mechanism of injury needs to account for the events leading to the injury, and should include the playing situation and player/opponent behavior as well as a detailed description of whole body and joint biomechanics at the time of injury (see Figure 2). A number of different approaches can be used to describe injury mechanisms (Krosshaug et al., 2005), however, athlete interviews are by far the most common approach used for studying injury mechanisms (Krosshaug et al., 2005).

To enable comparisons between studies, it is important to develop clear definitions and terminology for injury mechanisms. So far, there are at most 12 studies in female football which in some form included information on injury mechanisms, with only one of these studies (Tscholl et al., 2007a) specifically aimed at assessing injury mechanisms. However, a variety of different terms have been used to describe the moment of injury occurrence.

The inciting event of injury has mostly been described as *"contact vs non-contact"* (Arendt & Dick, 1995; Heidt et al., 2000; Junge et al., 2004b, 2006; Agel et al., 2005; Emery et al., 2005; Faude et al., 2005; Dick et al., 2007; Hägglund et al., 2007; Tscholl et al., 2007a). Only five studies have more clearly defined "contact injuries" with additional information such as *"contact with another player"* (Hägglund et al., 2007; Tscholl et al., 2007a), *"contact with another player or equipment"* (Emery et al., 2005) or *"contact with a player, surface or other"* (Arendt & Dick, 1995; Dick et al., 2007). Other terms used to define injury mechanisms were *"circumstances, including foul play"* (Junge et al., 2004b, 2006) and *"activity at time of injury"* (Emery et al., 2005). Two studies did not define any specific terms or categories, but presented descriptive results (Becker et al., 2006; Waldén et al., 2007). Of the 12 available investigations, Faude et al. (2005), Becker et al. (2006) and Tscholl et al. (2007a) reported what appears to be the most informative results, and only these three studies are presented in Table 7.

Information on injury mechanisms in female football must be described as sparse. Based on the above listed 12 studies, contact injuries accounted for 26-61% of all injuries when based on athlete interviews; this proportion increased to 86% when injuries were captured by video

(Tscholl et al., 2007a). According to the comprehensive model of injury causation (Bahr & Krosshaug, 2005), a description of whole body and joint biomechanics for specific injury types is lacking in all studies.

Table 7. Terms used to describe injury mechanisms in female football.

Reference	Playing level	Injury	Injury mechanisms
Tscholl et al. 2007a	Elite	All	Contact (86%): tackles from the side (52%), from the front (38%), from behind (11%) Non-contact (14%): shooting, running, change of direction
Becker et al. 2006	Elite	All	Duels (26%), ankle inversion trauma (10%), sprinting, twisting and shooting (12-15%)
Faude et al. 2005	Elite	All	Contact (52%): tackling, foul play, collision Non-contact (48%): running, changes in direction, shooting, jumping, hit by ball

There are only six investigations available, five from male elite football (Giza et al., 2003; Andersen et al., 2004a, 2004b; Árnason et al., 2004c; Fuller et al., 2004) and now one recently published from female college football (Tscholl et al., 2007a), all in which information on injuries was obtained by a video-based analysis system. These studies show that video analysis most likely provides a more precise and reliable description of the injury mechanism compared to e.g. athlete interviews (Krosshaug et al., 2005). However, the differences seen in injury rates and injury patterns for female compared to male football players also suggest that the mechanisms leading to injuries may differ between males and females as well. Uncritical transfer of the knowledge from male elite football to female football or other levels of play is therefore not recommended.

To sum up, relatively little is known about specific injury mechanisms in female football. Knowledge from male football is valuable but not necessarily transferable to females. Further studies are needed to continue the work of Tscholl et al. (2007a) to clarify mechanisms of injuries in female (youth) football.

Injury prevention

So far only 15 injury prevention intervention studies have been carried out on a world-wide basis in football (Table 8) even though the first study was done as long as 25 years ago and with very promising results (Ekstrand et al., 1983). In this study, the intervention group sustained 75%

fewer injuries than the control group. More recently, research groups have tested different prevention approaches, such as orthoses (Tropp et al., 1985; Surve et al., 1994), balance training (Caraffa et al., 1996), eccentric hamstring strength training (Askling et al., 2003; Árnason et al., 2007), a video-based awareness program (Árnason et al., 2005), and multimodal exercise programs (Junge et al., 2002; Engebretsen et al., 2007; Hägglund et al., 2007). All prevention approaches except two (Árnason et al., 2005; Engebretsen et al., 2007) could report a reduction of injuries in the intervention period.

We do not know if this knowledge from male football can be transferred to females. In female football, less scientific work has been done, and until now, there are only three studies published on female football players alone (Heidt et al., 2000; Söderman et al., 2000; Mandelbaum et al., 2005). Additionally, there are two studies which included both genders (Hewett et al., 1999; Johnson et al., 2005) and athletes from several sports, including football players (Hewett et al., 1999). These five studies have focused on the prevention of injuries in general (Söderman et al., 2000; Johnson et al., 2005) or on ankle and knee injuries (Hewett et al., 1999; Heidt et al., 2000; Mandelbaum et al., 2005).

Hewett et al. (1999) evaluated the effect of a neuromuscular training program on the incidence of knee injuries in female team sport athletes, where 290 of 1 263 were football players. They found a trend towards a higher incidence of ACL and MCL (medial collateral ligament) injuries in the control group compared to trained female players in the intervention group.

In another non-randomized study, Heidt et al. (2000) examined the effect of a 7-week pre-season training program among 300 female football players at the high-school level (aged 14-19 years). A total of 42 players went through a training program consisting of warm up exercises, plyometrics (jump training), strength and flexibility training. Players in the intervention group had significantly fewer injuries than those in the control group. However, the results must be evaluated with caution due to the low study power.

Söderman et al. (2000) examined the effect of balance board training among 221 senior female players at various levels. The players were randomized to train on a balance board daily for 30 days, then three times a week during the season, or to the control group, training as normal. In contrast to the results of Caraffa et al. (1996) who performed a similar study on male semi-professional players, Söderman did not find any protective effect for ACL injuries in the intervention group. Again, the power of the study was low which suggests careful interpretation of the results in order to conclude that balance board training alone at least based on a home training program, is not sufficient to prevent ACL injuries in females.

In a five-month approach with male and female elite football players in Sweden, Johnson et al. (2005) identified players at high injury risk by screening them with a questionnaire for psychosocial risk factors. High-risk players (9 female and 7 male players) received intervention including relaxation and imagery training, which lowered the number of injuries within four months of intervention.

Mandelbaum et al. (2005) conducted a neuromuscular and sports-specific training program over two seasons on about 3 000 14- to 18-year old female football players. The intervention consisted of education, stretching, strengthening, plyometrics and sports-specific agility drills. Their results showed an 88% decrease in ACL injuries in the enrolled players compared to the control group during the first year. In year two, the reduction was 74%. However, this study was not randomized.

In conclusion, there is still a lack of well-designed studies on injury prevention among female footballers, most likely due to limited knowledge of the causes and mechanisms of injuries, which again makes it difficult to develop targeted preventive measures. As shown in studies from football and team handball, several programs have successfully incorporated one or more exercise components to prevent injuries, e.g. plyometrics, strength, neuromuscular training, or running and cutting movement patterns, to prevent injuries in female (Hewett et al., 1999; Heidt et al., 2000; Myklebust et al., 2003; Mandelbaum et al., 2005; Olsen et al., 2005) and male athletes (Askling et al., 2003). However, as compliance is a concern in injury prevention (Myklebust et al., 2003), it may be difficult to motivate coaches and players to follow such exercise programs merely to prevent injuries, unless there is a direct performance benefit, as well. Comprehensive neuromuscular training programs that combine plyometrics, core strengthening, balance, resistance or speed/agility training may improve several measures of performance concomitantly, and at the same time improve biomechanical measures related to lower extremity injury risk (Hewett et al., 2004; Paterno et al., 2004; Myer et al., 2005; Myer et al., 2006).

FIFAs Medical Assessment Research Center (F-MARC) has recently developed a specific training program, the “11” in order to prevent the four most common injury types in football, i.e. injuries to the ankle, knee, hamstring and groin. The exercises composing the “11” represent evidence-based rehabilitation exercises for lower limb injuries (F-MARC, 2005) and key exercises from other effective injury prevention programs. The “11” has been feasibility tested in a pilot study as “F-MARC bricks” (Junge et al., 2002) and thereafter been modified to the final “11”. However, this injury prevention program has not yet been scientifically tested. Injury prevention through the use of the "11", and its potential performance enhancing effects were studied in Papers I and II.

Table 8. Injury prevention studies designed to reduce the risk of injuries in female and male football players.

Reference	Level Number Age	Design Follow-up	Injuries	Intervention[1]	Effect of intervention
Female players					
Mandelbaum et al. 2005	Youth n=2946 (1041 in the intervention, 1905 in the control groups) 12-18 years	Prospective cohort 2 years	ACL	Neuromuscular training program flexibility, plyometrics, weight training	74-88% fewer ACL injuries in the intervention group
Söderman et al. 2000	Amateur n=221 (121 in the intervention, 100 in the control groups) x=20±5 years	RCT 7 months	Acute lower extremity	Balance board training at home; 10-15 min initially each day for the first 30 days, and then 3 times per week during the rest of the season	No injury reduction in the intervention group, but a significantly higher incidence of major injuries in the intervention group
Heidt et al. 2000	Youth n=300 (42 in the intervention, 258 in the control groups) 14-18 years	Prospective cohort 1 year	All	7-week pre-season program of sportspecific conditioning, plyometric training, sport cord drills, strength and flexibility exercises; 1-2 times weekly	41% fewer injured players in the intervention group
Hewett et al. 1999	Youth n=290 (97 in the intervention, 193 in the control groups) 14-18 years	Prospective cohort 1 year	ACL, MCL	Neuromuscular training program flexibility, plyometrics, weight training; 60-90 min 3 times weekly for 6 months in pre-season	Trend towards fewer knee injuries in the intervention group
Female and male players					
Johnson et al. 2005	Elite n=32 (16 in the intervention, 16 in the control groups Females: 20.1 yrs Males: 22.9 years	RCT 6 months	All	Cognitive-behavioral training with relaxation and imagery training	83% fewer injuries in the intervention group

[1]The control groups were generally asked to continue their regular training habits and train as usual.
RCT=Randomized controlled trial

Table 8. To be continued.

Reference	Level Number Age	Design Follow-up	Injuries	Intervention[1]	Effect of intervention
Male players					
Hägglund et al. 2007	Amateur n=482 15-46 years	RCT 10 months	All	10-step rehabilitation program	66%-75% fewer re-injuries in the intervention group
Engebretsen et al. 2007	Elite + amateur n=508 Age unknown	RCT 8 months	Ankle and knee sprains, hamstring and groin strains	Neuromuscular and/or strength training programs	No effect in the intervention group
Árnason et al. 2007	Elite n= ca. 600 Age unknown	Prospective cohort 2 seasons	Hamstring strains	Stretching, Flexibility and/or eccentric hamstring training	35% fewer hamstring strains in the group training with both eccentric strength and flexibility compared to that training flexibility alone
Árnason et al. 2005	Elite + amateur n= ca. 350 Age unknown	RCT 6 months	All acute	Educational video-based awareness program	No effect in the intervention group
Askling et al. 2003	Elite n=30 24 years	RCT 11 months	Hamstring strains	Pre-season strength training	70% fewer injured players in the intervention group
Junge et al. 2002	Youth n=194 14-19 years	Prospective cohort 1 year	All	Multi-modal program	21% fewer injuries in the intervention group (n.s.)
Caraffa et al. 1996	Elite + amateur n=600 Age unknown	Prospective cohort 3 years	ACL	Balance training	87% fewer ACL injuries per team in the intervention group
Surve et al. 1994	Elite + amateur n=504 Age unknown	RCT 1 season	Ankle sprains	Semirigid ankle orthosis	60% lower incidence of ankle sprains in the intervention group, no effect for players without previous ankle sprains
Tropp et al. 1985	Amateur n=439 Age unknown	RCT 6 months	Ankle sprains	Either ankle orthosis or balance training	71-82% fewer injured players among those with previous sprains regardless of intervention, no effect for players without previous ankle sprain injuries
Ekstrand et al. 1983	Amateur n=180 17-37 years	RCT 6 months	All	Multi-modal program	75% fewer injuries in the intervention group

[1]The control groups were generally asked to continue their regular training habits and train as usual.
RCT=Randomized controlled trial

Aims of the thesis

The overall research aims of this thesis were to prevent injuries and explore the potential for combining injury prevention training with performance increases in female youth football.

The specific aims were:

1. To investigate the effect of an injury prevention program, the "11", on performance in adolescent female football players (Paper I).
2. To explore the effect of the injury prevention program, the "11", on injury risk in female youth football (Paper II).
3. To compare the risk of injury on artificial turf versus natural grass among young female football players (Paper III).
4. To analyze whether injury history and lower limb function assessed by a self-administered questionnaire represent risk factors for injury (Paper IV).
5. To identify players at risk for injury by assessing psychological player characteristics (Paper V).

Methods

Inclusion of players, study design and data collection

This thesis consists of two separate projects, Project I and Project II, on different study populations. Both projects were randomized controlled intervention trials, and the results are described in five papers. Four out of the five papers are based on the same study population (Project II), while Paper I is based on Project I. All data presented in these papers were collected prospectively.

In the autumn of 2004, young female football players, 16-18 years of age, were tested on physical performance right before and following a 10-week exercise intervention period (Paper I). In Project II, data from 14- to 16-year old female football players, who were introduced to an eight-month intervention period, were collected from March throughout October 2005 (Papers II-V). The design of the two projects comprising this thesis is described as a flow chart in Figure 3 and Figure 5.

Project I (Paper I)

Population (Performance aspects of an injury prevention program)

Female adolescent football players (mean age 17.1±0.8, range 16-18 years) from two elite sport high schools in Oslo (Norway) were invited to participate. Of these 36 players, 18 players from each school were available. Two of them, one from each school, had longstanding injury problems and had to be excluded before the start of the study. After performing the pre-tests, the remaining 34 players were randomly assigned, stratified by school, to either an intervention group (n=18) or a control group (n=16). After randomization, one player in the control group declined further participation in the study for reasons unknown. During the study period, one player in the intervention group quit playing football and another in the control group suffered a serious injury. Both were excluded before the post-tests, leaving 17 players in the intervention group and 14 players in the control group.

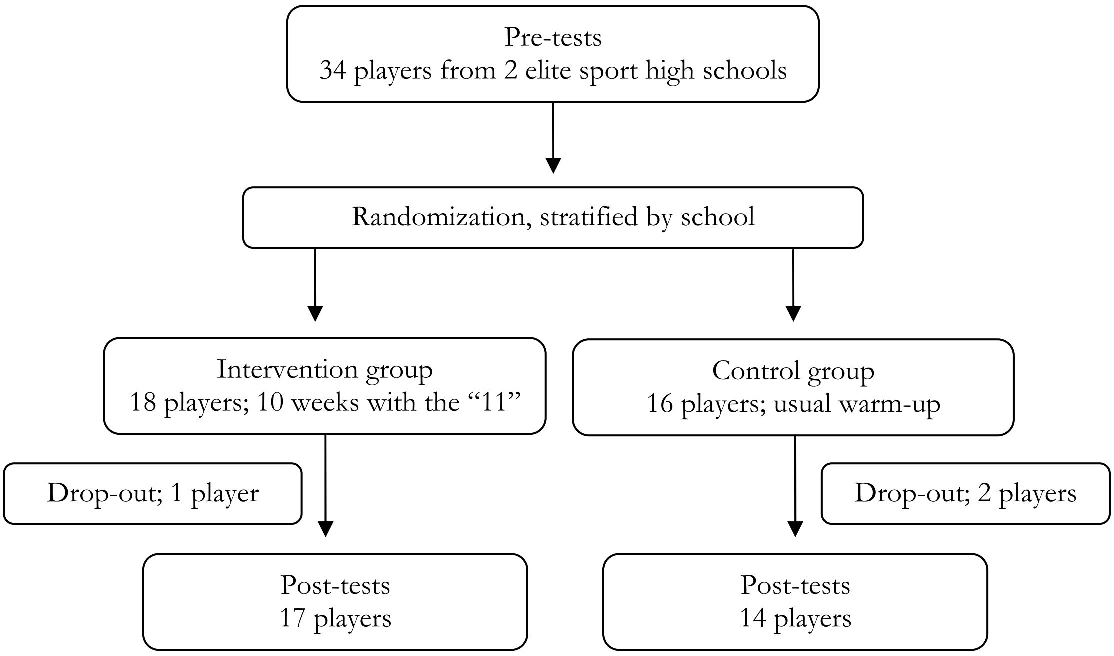

Figure 3. Flow chart describing the study design and follow-up (Project I).

Pre- and post-tests

All the pre- and post-tests took place at the Norwegian School of Sport Sciences and at the neighboring Norwegian Olympic Training Center. The test battery included five test stations and was completed within 3-4 hours. The tests were done in the same order for each player for the pre- and the post-tests. Before the pre-tests, all the players took part in a test-run 5-10 days before the pre-tests to be familiarized with the testing procedure. The test-run and all the pre- and post-tests were led by the same experienced lab personnel. The following performance tests were chosen to be part of the testing:

Lower extremity isokinetic and isometric torque. The strength testing protocol consisted of tests for hamstring and quadriceps muscle functions, including concentric, eccentric and isometric tests (REV9000, Technogym®, Gambettola, Italy). Concentric isokinetic quadriceps and hamstring torques were measured at test angular velocities of $60°\cdot s^{-1}$ and $240°\cdot s^{-1}$, while eccentric isokinetic torque was tested at $60°\cdot s^{-1}$ only. The quadriceps/hamstring ratio (Q/H ratio) was calculated for all angular velocities for concentric torque, and for concentric quadriceps torque versus eccentric hamstring torque at $60°\cdot s^{-1}$. Isometric quadriceps and hamstring torques were measured at 30°, 60° and 90° of knee flexion. Strength was reported as the peak torque recorded (Nm).

Isometric hip strength. Isometric strength of the adductor and abductor muscles was tested with a hand-held dynamometer (Hydraulic Push-Pull Dynamometer, Baseline® Evaluation Instruments, White Plains, New York, USA).

Jumping ability. Three different types of jump tests were performed. Countermovement jumps and drop vertical jumps were performed on a force plate (AMTI, LG6-4-1, Watertown, MA 02472, USA), and a 15-s continuous rebound jump test was carried out on a Bosco jump mat (Ergojump, Globus Italia, Codogne, Italy).

Video analysis. A digital video camera (30 Hz) secured to a tripod was placed on the opposing side and 3 m from the force plate during the jumping tests. Two-dimensional frontal plane knee angles were obtained for each countermovement or drop vertical jump by using a software program (NEAT, NEAT Visions Inc, Florida, USA).

40 m single sprint. The sprint test assessing football players' maximum speed was performed on an indoor track.

Speed dribbling. The players performed a 20 m shuttle run both with and without a ball, aimed at assessing coordinated dribbling under time pressure and speed. The test was based on a straight dribbling test, where five cones were placed in a straight line 2.8 m, 4.8 m, 6 m, 8 m and 10 m from the start line (perpendicular to the line).

Shooting distance. After a free run-up, the players, using their dominate leg, kicked the ball from a dead position as far as possible within a pre-defined 23°-angle sector.

Intervention

The "11" is a time-efficient injury prevention program, and can after a short period of familiarization be completed in 15-20 minutes (F-MARC, 2005). The exercises require no equipment except a ball, and are meant to be part of the warm-up period each training session, replacing similar exercises often used during warm-up. The "11" includes ten exercises, focusing on core stability, balance, dynamic stabilization, and eccentric hamstring strength (Figure 4 and Table 9). The original "11" also consists of an 11^{th} component, fair play, which was not included as part of the program tested in either Project I or II.

The intervention period lasted from September 8^{th} until November 26^{th}, 2004, interrupted by a one-week break (school holiday). The players in the intervention group received a balance mat each (40 x 50 cm^2, 7 cm thick; Alusuisse Airex, Sins, Switzerland 2000) and had during the 10-week intervention period scheduled training with the intervention exercises three times weekly.

The intervention program, the "11", was introduced to the players by a physical therapist. More than 90% of the intervention sessions were supervised by the project leader and staff.

Figure 4. The injury prevention program, the "11" (Reprinted with permission from F-MARC).

Table 9. Exercises and repetitions of the "11" used as a structured warm-up program (F-MARC, 2005). The single-leg balance exercises (4, 5 and 6) were done on a balance mat once the players were able to perform these exercises properly on stable ground.

Exercises	Description	Repetitions
Core stability		
The bench (1)	Leaning on your elbows in the prone position, lift the upper body, hips and knees so that the body forms a straight line from the shoulder to the heels. Hold this position.	15 seconds x 4 repetitions
Sideways bench (2)	Leaning on one elbow in the side position, lift top leg and hips until the shoulder, hip and top leg are in straight line and parallel to the ground. Hold this position.	15 seconds x 2 repetitions on each side

Table 9. To be continued.

Exercises	Description	Repetitions
Balance		
Cross-country skiing (3)	In single-leg stance, continuously bend and extend the knee of the supporting leg and swing the arms in rhythm.	15 seconds x 2 repetitions on each leg
Chest pass in single-leg stance (4)	Partner exercise with both players in single-leg stance. Throw a ball back and forth.	15 seconds x 3 repetitions on each leg
Forward bend in single-leg stance (5)	As in (4). Before throwing back, touch the ball to the ground without putting weight on it.	15 seconds x 3 repetitions on each leg
Figure-of-eights in single-leg stance (6)	As in (4). Before throwing back, move the ball in a figure-eight through and around both legs.	15 seconds x 3 repetitions on each leg
Plyometrics		
Line jumps (7) (Sideways, forwards-backwards)	Two-leg jumps sideways over a line and forward-backward as quickly as possible.	15 jumps of each type
Zigzag shuffle (8) (Forwards and backwards)	Shuffle sideways with a low center of mass to the first cone, turn so that the other shoulder points to the next cone and complete the zigzag course as fast as possible.	2 repetitions in each direction (20 m)
Bounding (9)	Spring as high and far as possible off the supporting leg. Bring the knee of the trailing leg up as high as possible and the opposite arm in front of the body. Continuous bounding, switching legs on each take off.	10-15 jumps (20 m) x 3 repetitions
Strength		
Nordic hamstrings (10)	Lower legs are held stable by a partner. Slowly lean forward keeping the upper body and hips straight and by using the hamstring muscles to resist the forward falling motion.	5 repetitions

Project II (Papers II-V)

Population Paper II (Preventing injuries)

All teams (n=157) in the southeast regions of Norway registered to participate in the Under-17 league system (U17) in the 2005 season were invited to take part in the study. Of these, a total of 113 teams (72%) volunteered to be included. No information or further follow-up were available for the 44 teams that declined to participate in the project.

A player was entered in the study if she was registered by the team as participating in the U17 league system, which means that she had to be 16 years or younger. However, teams competing in the U17 league could apply for exemption to use older players, if they did not have enough eligible players. Players who were injured at the start of the study were included, but the pre-existing injury was not included in the data analyses. Players and teams who left the team during the study period were included in the analyses for their time of participation, and new players who joined the teams after March 1st were included in the study for their time of participation.

Four teams declined to participate in the trial after the randomization of the 113 teams had been completed: one in the intervention group (did not have a coach) and three in the control group (withdrew from participation in the league system). The players (n= 72; estimated) of these four teams were excluded from the study. The remaining players in the two groups were similar in age (15.4 ± 0.8 yrs [SD] in both groups) and age distribution. Thus, the final sample consisted of 109 teams and 2 020 players; 58 teams (1 073 players) in the intervention group and 54 teams (947 players) in the control group, respectively. Two teams (30 players) in the intervention group withdrew from the study during the summer break.

During the study period, 21 players in the intervention group (2.2%) and 27 players in the control group (2.5%) were reported to have quit football with the teams involved in the project for reasons unknown.

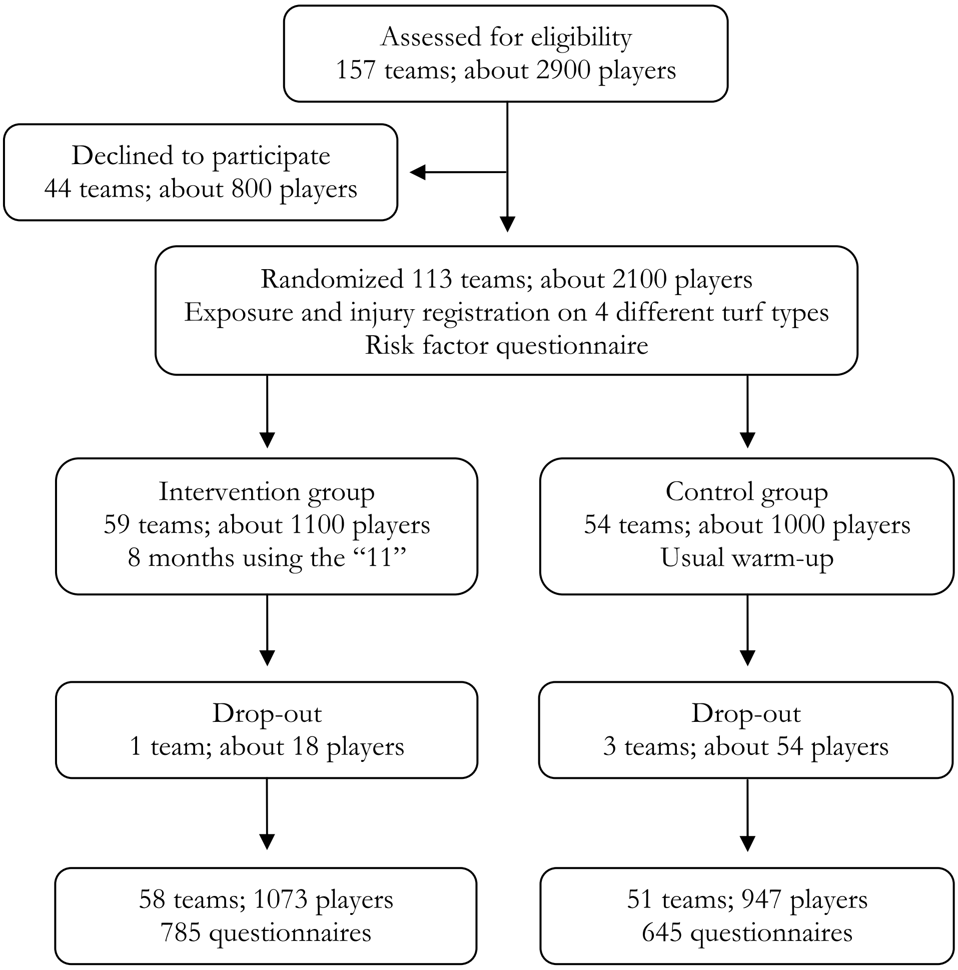

Figure 5. Flow chart describing the study design and follow-up (Project II).

Population Papers III-V (Injury risk on artificial turf; Risk factors for lower limb injuries; Psychological injury risk factors)

These three studies (Papers III-V) were originally planned to include only the control group of the prevention trial (Paper II). However, since there were no significant differences in the injury rate between the intervention and control groups, all players (n= 2 020) were included in the following three papers.

Exposure registration (Papers II, III)

All playing activities between March 1st and October 31st, including training exposure and seasonal and tournament match exposure, were recorded on a team basis and were played on four different turf surfaces: natural grass, artificial turf, gravel and indoor floor. The injury incidence was calculated as the number of total injuries per 1000 player hours both in match play and training. To calculate match exposure, match playing time was multiplied by 11 and for training exposure training time was multiplied by the average monthly player attendance

Injury definitions (Papers II-V)

An injury was registered if it was sustained during training or match play and caused the player to be unable to fully take part in match or training sessions the day following the injury *(time loss* injury) (Fuller et al., 2006). 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. Recurrent injuries were defined as an injury of the same type and the same site as an index injury and which occurred after a player had returned to full participation from the index injury. In addition to turf type, the localization of the injury, the type of injury, and the injury circumstances (contact versus non-contact) were also recorded. 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* (8-21 days) and *major* (>21 days) (van Mechelen et al., 1992).

Injury registration (Papers II-V)

To monitor injuries and playing exposure, 18 physical therapists were recruited as injury recorders and assigned to the teams (typically 5-7 teams each) to record injuries during the period from March 1st through October 31st 2005. All coaches were asked to keep a continuous log of all data requested. The coach of each team was contacted by telephone and/or e-mails at least once a month to record new injuries, as well as all training and match activities, including exposure on the four different turf types. Injured players were interviewed by the injury recorders to assess aspects of the injury based on a standardized injury questionnaire. None of the injured players were examined or treated by any of the authors or injury recorders involved in the study.

Intervention (Paper II)

The final 58 teams in the intervention group received 15 balance mats each (40 x 50 cm^2, 7 cm thick; Alusuisse Airex, Sins, Switzerland 2000). Additionally, all coaches and players received a detailed brochure which described the intervention program, focusing on how the exercises should be performed properly, as well as on common errors.

The prevention program was introduced to the teams in the intervention group in the beginning of the pre-season, with guidance and surveillance by 26 instructors, mainly from the Norwegian Football Association, each of them responsible for 2-3 teams. The instructors had been introduced to the intervention program during a seminar, where they received theoretical and practical training in the program and were instructed in how to teach it to the teams. Implementation of the prevention program in the selected teams by the instructors took about 1½ months, which means that 95% of the teams were instructed between March 1st and April 12th.

The coaches were asked to use the program every training session for 15 consecutive sessions and thereafter once a week during the rest of the season, replacing any warm-up routine normally used by the team. At the first prevention training session, the coaches in the intervention group received a compliance form to record participation in the prevention program. Detailed information was requested on the duration of each prevention session, and the number of attending players. Information on any preventive training used in the control group, including their type and frequency, was obtained at the end of the season.

Risk factor questionnaire (Papers IV, V)

In the period March to April 2005, all players were asked to complete a detailed self-administered questionnaire concerning their sports participation, history of previous injuries to the knee, ankle, hamstring or groin, as well as to the present function of the lower limb joints and muscles (Paper IV). In addition, psychological player characteristics were asked for in the final part of the questionnaire (Paper V).

Ankle and knee function were classified using the Foot and Ankle Outcome Score (FAOS) (Roos et al., 2001) and the Knee and Osteoarthritis Outcome Score (KOOS) (Roos et al., 1998) forms, while similar forms were constructed to classify hamstring and groin function by adapting questions from the FAOS and KOOS forms to these muscle groups.

Psychological player characteristics were assessed by five established self-evaluation questionnaires covering players´ perception of success and motivational climate, life stress, anxiety and coping strategies (Petrie, 1992; Roberts & Ommundsen, 1996; Carver, 1997; Abrahamsen et al., 2006).

Distribution of the questionnaire: The questionnaire was introduced to the players at a team meeting by staff, who also were present while the players answered the questions. The players took about 60 min to answer the full questionnaire, and it was ensured that the players had adequate privacy when answering the questions. Completed questionnaires were missing for those players who did not attend the scheduled team meetings and for teams that were not able to arrange team meetings for that purpose: two intervention and five control teams.

Statistical methods

All data were statistically analyzed using SPSS (SPSS for Windows, versions 13.0-15.0, 2005-2007, SPSS Inc, Chicago, USA) or STATA (STATA for Windows, version 8.0, 2003, Stata Corporation, Lakeway Drive, Texas, USA).

Descriptive data were generally presented for variables as mean values with standard deviation (SD) or 95% confidence intervals (CI); e.g. for performance variables (Paper I), anthropometrics and player history (Papers I-V), risk exposure and injury rates (Papers II, III), lower limb function scores (Paper IV), and psychological factors (Paper V).

Intervention and control groups (Paper I) as well as injured and non-injured players (Papers IV) were compared using Student's t-test for independent groups, and results were presented with SD and 95% CI.

Comparisons of categorical variables were analyzed by using a χ^2 test or Fisher's exact test for small numbers (Papers II-V). These data included the frequency of injuries, such as injury type, location, severity, and injury mechanisms (Papers II, III), and the number of players with previous versus new injuries (Papers IV, V), or with high levels of stress versus new injuries (Paper V).

Injury incidences were calculated for all injuries, including subgroups of injuries, in the intervention and control groups (Paper II), and for play on artificial turf and natural grass (Paper III). Injury rates were presented as the number of injuries per 1000 playing hours with corresponding 95% CI using a Poisson model with constant injury rates in total and for match and training injuries, separately (Papers II, III). Injury incidences were compared between groups using z-statistics based on the Poisson-model (Altman, 1994), and data were presented as rate ratios (RR) with a 95% CI.

In Paper II, one-way ANOVA was used to estimate the intracluster correlation coefficient (ICC) to obtain the variance inflation factor (IF) for comparison with planned sample size in the intervention and control groups. In the same paper, exposure time and injuries were included in the analyses after the first prevention training session had been completed by an intervention team and from the same date in a control team randomized to the same block.

Papers III-V were based on a secondary analysis of the data presented in Paper II. Since no differences were seen in injury rates between the intervention and control groups, the analyses did not factor in group assignment, and injuries of the total 2 020 players could be treated together in Papers III-V.

In Papers IV and V, analyses were carried out using both player as well limb as the unit of analysis. Taking the dependency of multiple injuries into account, the potential risk of anthropometric and player history data, previous injuries and different lower limb function scores (only Paper IV), all used to identify new injuries, were analyzed using Poisson regression models, fitted by generalized estimating equations (GEE) (Liang & Zeger, 1986).

In Paper IV, the regression models were adjusted for the effects of clusters (person and team, using geographic region as surrogate for team). Rate ratios with 95% CI associated with a 1 SD decrease in the exposure variable (function score: total and subscores) were reported to compare the risk for new injuries between players. Similarly, with limbs as the unit of analysis, RR with 95% CI were given for a one unit increase in the number of years of play, previous injuries, as well as a one unit change for the groups of players with low function scores. Odds ratios (OR) with 95% CI were calculated for the group of players with previous versus new injuries (Papers IV, V). Based on a simplified model with limb as the unit of analysis and each injury treated as a separate case, the sensitivity and specificity of self-reported previous injuries and low function scores to predict new injuries were calculated.

In Paper V, in addition to Poisson regression models, intercorrelations between all psychological variables were presented by Cronbach's α. Groups of previously and prospectively injured and non-injured players were compared using MANOVA, with the various psychological factors as dependent variables, and with univariat post-hoc analyses when MANOVA was significant. Odds ratios with 95% CI were obtained for the group of players with high levels of life stress versus new injuries.

In all papers, the level of two-tailed significance was chosen to be $\alpha=0.05$.

Ethics

Both projects were approved by the Regional Committee for Research Ethics (Health Authority of South Norway), and written consent was obtained (see Appendix). Before the pre-testing (Project I; Paper I) and before the start of the pre-season (Project II; Papers II-V), the players received written and oral information about the study, and it was emphasized that participation in the actual investigation was voluntary. All collected data were treated confidentially.

Results and discussion

Performance aspects of an injury prevention program (Paper I)

In Paper I, we investigated the effect of ten weeks of training with the injury prevention program, the "11", on a range of performance tests in youth female football players. The intervention group completed a maximum of 30 training sessions with the "11", and the mean number of completed sessions was 22±10 (range 0-29). When using a pre-defined cut-off of 20 completed training sessions with the "11", 12 of the 17 players in the intervention group reached this target. None of the players in the control group performed exercises similar to the "11".

No increase in performance after 10 weeks of training with the "11"

Post-testing of 31 out of the original 34 players did not reveal significant differences in between-group changes (intervention versus control group) in isokinetic or isometric thigh strength, isometric hip adduction or abduction strength, jumping ability, single sprint, nor in football tests (see Table 2 in Paper I for details). The results of a per-protocol analysis, based on the 12 players who completed at least 20 sessions, did not find any improvement either. Regardless of group assignment, the mean change in performance from baseline to the post-tests for the different variables was about 2%, ranging from -14% to 7% in the intervention group and from -12% to 11% in the control group.

The power of the study would have been acceptable to detect a change of 12 Nm in eccentric hamstring strength and 2.7 cm in jumping ability, equivalent to an improvement of approximately 10%. Such enhancements in performance have been documented in other studies with 6 to 12 weeks of training when using different and more intensive training protocols (Hewett et al., 1999; Askling et al., 2003; Mjølsnes et al., 2004). However, based on the observed mean differences, more than 300 players in each group would have been needed to rule out a type-2 error for these values.

We concluded that the training volume and intensity for each of the exercises of the "11" was most likely too low to result in performance improvements. These aspects will be discussed further in relation to the results from Paper II. However, our ability to detect all potential improvements in performance through the test battery available may also be limited.

Performance test battery

The test battery used in Paper I was thought to be the best available for assessing the effect of the "11" program. The physiological variables were measured using established methods and tests with acceptable reliability, and each of the tests selected were assumed to be valid for its purpose.

The same strength test protocol for isokinetic lower limb torque has been used earlier, and the measurements at $60°\cdot s^{-1}$ and $240°\cdot s^{-1}$ have shown high test-retest reproducibility (Raastad & Hallén, 2000). Additionally, isokinetic strength is a safer and more reliable measure of strength in persons not familiar with free weight training, as were most of the young female players in the study (Svensson & Drust, 2005). The reliability of the handheld dynamometer has been assessed (Bohannon, 1998; Krause et al., 2007), and care was taken to hold the dynamometer as stable as possible at the predefined position. Countermovement jumps and vertical drop jumps as well as sprint performance are standard tests to assess jumping ability and maximum speed in football players. The same testing procedure was used by for example Cometti et al. (2001) and Wisløff et al. (2004). The reliability and validity of the jumping tests are well described in the literature (Bosco et al., 1983), and have been used in numerous similar studies since the late 1970s. In an investigation to obtain data on the validity and reliability of a football skill test battery, the "speed dribbling test" was successfully been used by Reilly & Holmes (1983) in a group of young players. The shooting distance test to assess kicking performance has been used in young male football players by Rösch et al. (2000). However, its reproducibility has not been assessed. In summary, all of the tests used, except shooting distance, are well described in the literature and established as the most commonly used methods to measure performance.

However, this test battery as a whole has not previously been applied to test performance in football players, and the tests have not been reliability tested on young female football players specifically, which calls for careful interpretation of the results. In addition, the specificity of the tests is clearly not optimal. There is a high degree of mode specificity for e.g. strength training, meaning that one will need a test that is very similar to the exercise being trained to fully detect a potential improvement (Svennson & Drust, 2005). As an example, isokinetic strength tests do not reflect the movements of the limbs involved during sprinting, kicking a ball, or jumping (Cometti et al., 2001). Wisløff et al. (1998) therefore suggested that tests employing free weights would reflect the functional strength of the football player more accurately.

Preventing injuries in female youth football (Paper II)

In Paper II, we tested the effect of the injury prevention program, the "11", on injury risk among 14-to 16-year old female players. During the study period, the mean number of training sessions with the "11" among the 58 teams in the intervention group was 23±9 (SD). Average player attendance was 67±10%, and the "11" was used at 52% of all training sessions during the period, 60% of the total number of training sessions before and 44% of the training sessions after the summer break. Only 14 of the 58 intervention teams (24%) reached the cut-off of 20 prevention training sessions before the summer break.

No effect of the "11" on preventing injuries

In the intervention group 19% of the players sustained at least one time loss injury during the eight months of injury recording, compared to 20% in the control group (P=0.50). The overall injury incidence, as well as injury rates for specific subgroups of injuries, did not differ between the intervention (3.6 injuries/1000 h, 95% CI 3.2 to 4.1) and control groups (3.7, CI 3.2 to 4.1; rate ratio RR=0.99, CI 0.83 to 1.19; P=0.94) nor in the incidence for any type of injury. The analysis did not reveal a significant difference between those teams who performed at least 20 prevention training sessions before the summer break (defined as being *compliant*) compared to those who completed fewer than 20 sessions (*non-compliant*) or compared to the control group (see Table 4 in Paper II for details).

The main strength of the present investigation was its design as a randomized controlled trial with a large sample size. However, even if the sample size estimations done before study start were accurate (intraclass correlation coefficient ICC=0.06, inflation factor IF=1.8), study power was still limited. The final sample of 2 020 players provided a statistical power of 0.76 to detect a group difference of 40% in the number of players with a knee or ankle injury. This also means that the effect of the program on specific injury types could not be assessed reliably.

We concluded that the compliance of the teams in the intervention group was insufficient to result in an injury reduction compared to the teams in the control group. However, there is probably a potential to improve the exercise prescription of the "11" as a warm-up program to facilitate its implementation as an injury prevention program in female youth football.

Compliance

By using the cut-off of 20 initial prevention training sessions we could compare compliance with two previous projects in team handball from our research group (Myklebust et al., 2003; Olsen et al., 2005). In these projects, compliance was defined as having carried out 15 prevention training sessions within a pre-defined time period: 5 to 7 weeks (Myklebust et al., 2003) or four months (Olsen et al., 2005) However, in youth football, there is a longer mid-season summer break, matches are usually played on weekdays, and we expected a lower and more variable player attendance in training. To get a similar training frequency as the team handball studies, we increased the cut-off to at least 20 prevention training sessions within the first four months.

Based on this, the overall compliance was much lower than in youth team handball (Olsen 2006, personal communication) during the first half of the season (24% vs. 67%). Therefore, it seems unlikely that an effect on injury rate could be detected unless the compliance was substantially higher than the 24% reported in Paper II. Thus, the present study shows the importance of obtaining compliance data.

Contamination

Randomized controlled trials (RCT) are considered to be the gold standard for assessing the efficacy of intervention measures, and they provide the strongest evidence of a cause-effect relationship (Bahr & Holme, 2003; Thacker et al., 2003; Emery, 2005). Nevertheless, contamination of the intervention treatment to the control group is a relevant issue, when using RCTs (Emery et al., 2007). To diminish contamination, we used a cluster design to block-randomize 2x2 teams from the intervention and control groups of the same geographic region. This was to minimize the effect of between-team variations related to potential confounding factors such as attitudes to injury prevention, player skill and team level, playing intensity, and referee attitude. Such cluster effects were also accounted for when analyzing the data. In addition, physical therapists involved in exposure and injury collection were blinded to which group their teams belonged.

However, as experienced in the first project (Paper I) and clearly shown by the low compliance in Paper II, the main challenge with intervention trials such as these is not contamination to the control group, but motivating the players and teams in the intervention group to follow the prescribed intervention program. By the end of the season, we made phone calls to all the coaches in the control group to ask them about their warm-up exercises, training, and injury prevention routines. As mentioned above, none of these teams reported to have performed structured exercises similar to the “11”. Also, more than 90% of all intervention sessions in both elite sport high schools in Paper I were supervised directly. We therefore had excellent control on how the training sessions, and also the warm-up periods for the control groups, were carried out

- mostly with jogging and ball-based exercises. Our experience with former injury prevention projects (Myklebust et al., 2003; Olsen et al., 2005) is that players, even at the elite level, do not initiate injury prevention training on their own, unless a coach actively includes such training as part of the team's regular training program. As expected, the young players in the control groups did not show any interest in doing the exercises on their own, and we have no indications that they did similar exercises in their spare time. Contamination is therefore not thought to have biased our results in any of the two intervention studies.

Low volume and intensity of the "11"

In contrast to successful injury prevention programs from football (Caraffa et al., 1996; Askling et al., 2003; Mandelbaum et al., 2005; Árnason et al., 2007; Hägglund et al., 2007), team handball (Myklebust et al., 2003; Wedderkopp et al., 2003; Olsen et al., 2005), basketball (Emery et al., 2007) or mixed team sports (Hewett et al., 1996, 1999), the exercise prescription of the "11" did not provide a possibility for variation and/or progression. Thus, since the exercise stimulus was constant it may be that the exercise intensity of the "11" was insufficient to result in performance enhancements (Paper I) or injury reduction (Paper II). In these two intervention projects, the "11" was used as a warm-up program, and we therefore limited the duration of the whole program to 15-20 min. This also restricted the ability to increase the number of repetitions substantially, and the progression of the training stimulus was clearly lower than in other programs (Hewett et al., 1996; Heidt et al., 2000; Askling et al., 2003; Mjølsnes et al., 2004; Myer et al., 2005; Myer et al., 2006). A lack of variation in warm-up may also have resulted in reduced motivation among coaches and players and so affected compliance.

Content of the "11"

As the exercises composing the "11" have not been selected to target specific player populations based on age, gender or skill level, they may not have been appropriate to address the needs of the specific population of young, female players studied in this thesis. As outlined in the introduction and confirmed by the present study (see Paper III for details), the injury pattern among young female players seems to differ from that of male football players (Junge et al., 2004a; Price et al., 2004; Hägglund et al., 2005b; Waldén et al., 2005a; Le Gall et al., 2006), where groin and hamstring injuries represent as much of a problem as knee and ankle sprains. Among female football players, knee and ankle injuries predominate (Heidt et al., 2000; Östenberg & Roos, 2000; Söderman et al., 2000, 2001a; Faude et al., 2005; Giza et al., 2005; Mandelbaum et al., 2005). It therefore seems reasonable to suggest that injury prevention programs for this target group of females should put even more emphasis on lower extremity neuromuscular training to modify dynamic loading patterns and enhance knee and ankle control.

In both of the effective team handball injury prevention programs (Myklebust et al., 2003; Olsen et al., 2005), the focus was on technique training in high-risk situations in order to stimulate hip control and proper knee alignment. Compared to team handball (Olsen et al., 2003), there are so far no investigations that have been carried out to specifically assess injury mechanisms in female football, other than tackle maneuvers (Tscholl et al., 2007a, 2007b). Knowledge about non-contact injury mechanisms, in particular, is essential when designing injury prevention programs. Although it may be reasonable to assume that female football players also would benefit from not allowing the knee to pivot medially during cut and plant movements and after landings or when suddenly changing speed, as seen in team handball (Olsen et al., 2004), there is no direct evidence identifying injury mechanisms in female youth football. It may be that, knee (57% contact injuries; data not shown) and ankle injuries (66%) in female youth football to a greater extent result from direct contact with the lower extremity, resulting in less potential for intervention through neuromuscular training or fitness training. Our data of player-to-player contact injuries (58%, Paper III) are at the upper range of what has been reported earlier when applying athlete interviews (26-61%). However, more dynamic exercises resembling football play and injury-risk situations, like running with rapid changes of direction, two-leg landing with knee control after heading and perturbations (Giza et al., 2003; Andersen et al., 2004b; Árnason et al., 2004c), may be some ways to adjust the "11" program.

The issues addressed above have been considered in SPILLEKLAR! (in English: "Fit to play!"), a further development of the "11" which is being tested by the Oslo Sports Trauma Research Center in a large randomized intervention trial. The Fit to play! - program, includes initial and final running exercises, with three progression levels of strength, plyometrics and neuromuscular training exercises in between, in an attempt to target the young female player.

Injury risk on artificial turf and natural grass (Paper III)

As part of the injury prevention study (Paper II), we captured information on injuries and exposure on four different turf types throughout the entire study registration period (March 1st to October 31st), a total of 142 721 playing hours and 526 injuries. Due to a limited number of injuries and exposure on gravel and indoor floor, the purpose of Paper III was to compare the injury risk on artificial turf to that of natural grass. These turfs accounted for 79% of all exposure and 89% all injuries recorded.

No increased injury risk for play on artificial turf compared to natural grass

The overall (acute and overuse) injury incidence was 4.5 per 1000 playing hours (95% CI 4.0 to 5.0) on natural grass and 3.3 injuries per 1000 hours (CI 2.7 to 3.8) on artificial turf. However, the relative exposure during matches was higher on grass (67% of all match exposure) compared to artificial turf (23%). Acute injuries were more common in matches (75%, 343 out of 456 injuries) than in training. To minimize confounding, rate ratios between turf types and injury characteristics were calculated separately for match and training injuries. There were no significant differences observed in the incidence of acute injuries on artificial turf compared to grass for match injuries (with grass as the reference group; RR=1.05 [CI 0.81 to 1.35], P=0.72) or for training injuries (RR=0.98 [CI 0.65 to 1.49], P=0.93). We therefore concluded that playing on artificial turf was not a significant risk factor for injuries.

The results are in accordance with two recently published studies on elite male (Ekstrand et al., 2006) and on female and male US college players (Fuller et al., 2007a, 2007b). These studies are, besides our study, the first to assess injury risk on second and third generations of artificial turf. High friction and surface stiffness have been assumed to explain the higher injury rates observed on first generation artificial turfs in football (Engebretsen & Kase, 1987; Árnason et al., 1996), but the newer turf generations examined in the present and other studies (Ekstrand et al., 2006; Fuller et al., 2007a, 2007b) differ considerably from the older ones.

Even though the present study sample (2 020 players; 230 acute match injuries) must be considered large in the context of risk factor research, the statistical power to detect turf differences in injury risk for certain injury subgroups was still limited. Ekstrand et al. (2006) met similar challenges when interpreting their results on a sub-group level, whereas Fuller et al. (2007a, 2007b) applied a sufficient sample size.

Nevertheless, some differences and trends towards significant differences in injury rates between artificial turf and grass could be detected in Paper III. In matches, the incidence of serious injuries was significantly higher on artificial turf compared to grass (RR=1.98 [1.26 to 3.12], P=0.03). In addition, there were trends observed towards more ankle sprains (RR=1.47, [0.98 to 2.20], P=0.06), more knee injuries (RR=1.71, [0.96 to 3.05], P=0.07) and ligament injuries in general (RR=1.34, [0.97 to 2.00], P=0.07) on artificial turf than on grass.

Ligament sprains to ankles and knees often occur in situations when the player is out of balance while the loaded leg is fixed to the ground (Ekstrand & Nigg, 1989; Andersen et al., 2004b; Olsen et al., 2004). As more than 50% of all severe injuries in Paper III affected the lower extremity joints (31% ankle and 26% knee, data not shown), it may be that the shoe-surface friction plays a role in explaining the differences in injury rates between turf types, and that friction might have been higher on artificial turf. Ekstrand et al. (2006) also recorded a higher rate of ankle sprains on artificial turf, whereas Fuller et al. (2007a, 2007b) could not find any major difference in the severity, type or mechanism of match injuries on turf and grass by either female or male football players. In fact, in contrast to Paper III and Ekstrand et al. (2006), they found a lower match incidence of ankle sprains on artificial turf compared to grass among female players (RR=0.55, P=0.03) (Fuller et al., 2007a).

In Paper III, the players suffered a total of 11 ACL injuries: three on grass, four on artificial turf, two on gravel and two on indoor floor. With an injury rate of 0.08 ACL injuries per 1000 hours (95% CI 0.03 to 0.12), it appears that among female players below age 17 in Norway, ACL injuries still represent an uncommon injury type compared to that reported from other studies among older college players (Arendt & Dick, 1995; Agel et al., 2005; Fuller et al., 2007a, 2007b) or youth players (Mandelbaum et al., 2005). However, using athlete exposure as unit of risk, as was done in these studies (Arendt & Dick, 1995; Agel et al., 2005; Mandelbaum et al., 2005), may lead to an underestimation of risk exposure compared to injuries per 1000 hours and may partly explain the difference in ACL injury risk. In addition, the player ages in the two studies on youth players were different (14-16 vs 14-18 years).

The relationship between artificial turf and overuse injuries, which is a matter of discussion among players, coaches, and officials, was difficult to establish using the study design of Paper III or that of other researchers (Ekstrand et al., 2006; Fuller et al., 2007a, 2007b), where players constantly switched between artificial turf and grass. Per definition, overuse injuries have a gradual onset and can not be attributed to a specific inciting event nor to a particular turf type. Even if players reported that they first experienced symptoms during a particular match or training session, the injury may have in fact resulted from one or more previous sessions on a different turf type.

The question remains whether the results of Paper III can be applied to younger or older male players or to other levels of play. Studies on young male players, investigating injury risk on artificial turf, are lacking. As there are differences in injury patterns between male and female football players and injury mechanisms are expected to be gender-related, more studies are needed on this issue before the results from our study can be generalized to young male players and different playing levels.

Thus, recent evidence on the injury risk on artificial turf indicates that newer artificial turfs seem as 'safe' to play on as natural grass, even though there are inconsistent findings for injury subgroups.

Self-reported injury history and lower limb function as risk factors for injuries (Paper IV)

In the pre-season period of the 2005 season, a total of 1 430 players completed an injury risk factor questionnaire (71% of the entire cohort from Paper II). Of these players, 785 originally belonged to the intervention group (73% of all players in the intervention group) and 645 players to the control group (68%). The players represented a quite homogenous group in terms of age, weekly sports participation and body size, which also was mirrored by the fact that, in contrast to other studies with larger age ranges (Árnason et al., 2004; Faude et al., 2006), none of these variables were risk factors for new injuries.

Previous injuries and reduced function as significant injury risk factors

About 70% (n=1 003) of the 1 430 players had sustained at least one previous injury to an ankle, knee, hamstring or groin. A total of 21% (n=296) of these players were injured during 2005 with 22% (n=84) of the 380 injuries being re-injuries. The risk for sustaining a new injury during the study period was almost twice as high for players with a previous injury to the same region than for players without an injury history (OR=1.85 [95% CI 1.39 to 2.48], P<0.001).

Keeping in mind the young age of the players, it was surprising that the relatively low number of years the females had been involved in organized football play had such a strong impact on new injury risk (RR=1.12 [CI 1.04 to 1.22] for each additional year of play reported, P=0.003). In addition, the risk of sustaining a new injury increased with the number of previous injuries (RR=1.08 [CI 1.04 to 1.12] for each additional previous injury reported, P<0.001).

We also studied previous injuries as injury predictors for specifically ankle, knee, hamstring and groin injuries. As in several other investigations (Bahr & Bahr, 1997; Árnason et al., 2004b; Hägglund et al., 2006), the limb was used as the unit of analysis. Players with an injury history to the ankle (RR=1.18, CI 1.09 to 1.29, P<0.001), knee (RR=1.38, CI 1.22 to 1.57, P<0.001) or groin (RR=1.57, CI 1.16 to 2.12, P=0.004) were more likely to sustain a new ankle, knee or groin injury than players without previous injuries. However, injury risk was not increased for players with previous hamstring injuries to one of their limbs (P=0.22). The fact that we asked the players about previous hamstring injuries, but recorded thigh injuries as a group (without distinguishing between e.g. hamstring and quadriceps strains) may have confounded this risk factor analysis.

Given the potentially serious long-term health consequences following major knee and ankle injuries (von Porat et al., 2004; Anandacoomarasamy & Barnsley, 2005; Myklebust & Bahr, 2005), analyses of risk factors for lower limb injuries in female football are limited. A history of previous injury has consistently been pointed to as the strongest intrinsic risk factor, and the results from Paper IV are well in line with former studies concerning ankle (Ekstrand et al., 1983; Tropp et al., 1985; Surve et al., 1994; Árnason et al., 2004b; Kofotolis et al., 2007) and knee sprains (Árnason et al., 2004b; Hägglund et al., 2006; Waldén et al., 2006), even though Faude et al. (2006) in elite and Söderman et al. (2001b) in amateur female players did not find these associations.

The apparent inconsistency between our findings and those of Faude et al. (2006) and Söderman et al. (2001b) may have resulted from differences in the definition of a re-injury. Söderman et al. (2001b) chose to ask about injuries from the three months preceding the study. However, we included all previous injuries without specifying a time period. Faude et al. (2006) did not report their definition for re-injury. For future studies, previous injuries should be clearly defined in terms of *"same injury at the same site and location"*, and to specifically minimize re-call bias, *"how many months preceding the present study"* should be specified (Söderman et al., 2001b; Emery, 2005; Hägglund et al., 2005a).

Nevertheless, it may come as a surprise that previous injury is a significant risk factor in such a young group of players, given that their exposure to such injuries is limited. However, ankle sprain injuries have repeatedly been shown to be frequent among young and amateur female football players. Because these teams rarely have easy access to specialist sports medicine care, rehabilitation after previous injuries may be inadequate among the young females. An indication of this is that baseline function scores were lower in players with previous injuries to a particular region compared to previously uninjured players. Pain and other symptoms indicate a poorly rehabilitated injury or a joint that is not functionally stable during sports activities. It is therefore not surprising that reduced joint- and muscle-specific function was strongly associated with an increased injury risk to the same site for new ankle (RR=1.71 (95% CI 1.09 to 2.70], P=0.021) and knee injuries (RR=3.19 (CI 1.80 to 5.68], P<0.001). Decreased range of motion and strength, as well as increased pain, joint laxity and swelling are often present in functionally unstable ankle and knee joints following a trauma, and may contribute to low neuromuscular control and reduced athletic performance (Docherty et al., 2006). Although there were highly significant reductions in the hamstring (HaOS) and groin function scores (GrOS) in players with an injury history at baseline, the functional scores did not predict new thigh or groin injuries in these groups of players. This lack of association might simply be a type II error due to an insufficient number of muscle injuries, but it should be noted that the questionnaires for hamstring and groin function have not been validated previously.

Thus, based on the results of Paper IV, we concluded that a history of previous injury and reduced function at baseline were significant risk factors for new injuries to the same region and limb during the season.

The strong association observed between previous injuries, reduced function and new injuries in this young cohort underlines the importance of proper rehabilitation to prevent re-injuries. However, the usefulness of the joint- and muscle-specific questionnaire is limited by the low sensitivity in predicting new injuries through injury history and reduced function. Although the specificity was reasonably high (62-93%), the sensitivity was only 22-50%, depending on the region. Thus, it will not be possible to use the present questionnaires to target injury prevention programs to athletes at risk. Whether it is possible to develop a more sensitive and practical questionnaire to screen for injury is not known. However, based on the results of this study, questions covering “pain” and “joint- and muscle-specific symptoms” seem to be essential, at least when a player had reported an injury history. Pain seemed to be a useful indicator for limited function for all the four specific regions studied in the present paper. Therefore, a player who is not able to train without pain or other symptoms from a particular region should be advised to undergo rehabilitation and restrict participation in games, given the probable increased risk for a new injury.

Self-reported psychological characteristics as risk factors for injuries (Paper V)

In football, the psychological characteristics of players may be as equally important intrinsic injury risk factors as other clinical factors. The purpose of Paper V was to examine whether baseline psychological player characteristics assessed by a self-administered questionnaire represent risk factors for injuries in the subsequent season.

Mastery climate and high levels of life stress as significant injury risk factors

Players with an injury history perceived the motivational climate as performance oriented (r=0.08, P=0.003), and scored positive on ego orientation (r=0.07, P=0.007). Players characterizing themselves as ego-oriented, also scored positive on perception of a performance climate (r=0.33, P<0.001) and on task orientation (r=0.41, P<0.001). In addition, previous injuries were associated with having experienced a high level of life stress (r=0.18, P<0.001) (see Table 2 in Paper V for details). Thus, in line with the a-priori-hypothesis, significant differences in player characteristics were observed for players with and without previous injuries for perceived motivational climate and life stress.

Surprisingly, a perceived mastery (P=0.026), and not a performance climate, as expected, was significantly associated with new injuries among the young female players. A mastery climate might in certain team-coach relationships create an increased drive towards maladaptive perfectionism among players due to a strong emphasis on improvement and development, which again may force these players into injury risk situations. Of interest, Hall et al. (2007) found that high task and ego goals combined with elements of neurotic perfectionism explained 27% of the variance in the obligatory exercise behaviour of male college athletes.

Even though perceived anxiety before the start of the season was not associated with new injuries in our cohort (r=0.02; P=0.50), a stress response often is triggered if an athlete perceives that his or her resources are inadequate to meet the situational demands from e.g. a motivational climate. A constructive motivational climate in a team is considered to help players with a high perception of anxiety and life stress (Pensgaard & Roberts, 2000). In a mastery climate setting, a coach therefore should avoid and, if present, attempt to buffer high levels of negative perfectionism among players by somewhat downplaying the focus on development and rather increase enjoyment and playfulness.

Players who rated themselves low in coping strategies suffered from significantly more stressful life events (r=0.16 to 0.30, P<0.01). However, coping resources were neither correlated to previous injuries, except for emotion, nor to new injuries. Stressful life events are one of the most frequently studied psychosocial variables in the area of injury risk, and a greater likelihood of injury earlier was found in high-stress compared to low-stress athletes. There are theories that an accumulation of life stress may predispose the athlete to an athletic injury (Williams & Andersen, 1998; Andersen & Williams, 1999; Ford et al., 2000). Similar to these investigations, a higher sum-score of life stress (P=0.001) was strongly associated with injury risk among young football players. The risk of sustaining an injury increased by 67% for players with a high level of perceived life stress compared to those players with a low level of life stress (OR=1.67 [95% CI 1.30 to 2.18], P<0.001).

Successful performance in football does not only require the player to be healthy and physically fit, but also mentally prepared to play (Junge, 2000). Besides the prevention of injuries, the improvement of physical performance, technical and tactical skills, personality traits of the players in a team may be critical for a team's success. Some researchers have therefore hypothesized that certain athletes, as a result of their personality traits, have a particular predisposition towards getting injured (Taerk et al., 1977; Lysens et al., 1989; Junge et al., 2000). Despite the present relationships regarding perceived motivational climate, stress and injury risk, a personality profile typical for the "injury-prone" young female player was not identified.

In order to attenuate perceived life stress as an injury risk factor among young female football players, coaches must be aware of a player's total life stress situation. A positive motivational climate in a team has in many cases been considered with a mastery climate. However, too strong an emphasis on individual improvement and development should be avoided to lessen negative perfectionism and sport related stress among players. If stress-related discomfort is apparent among players, supplementation of cognitive capabilities, such as stress coping strategies, may contribute to creating a balance between psychological player characteristics and injury risk.

Conclusions

1. No significant effects were observed on different performance variables among adolescent female football players participating in a 10-week injury prevention program, the ”11”, compared to players who trained as usual. The exercise prescription of the “11” was most likely insufficient to result in measurable performance enhancements.

2. The main finding of the RCT on the injury prevention effect of the “11” was that no reduction in injury rates could be observed in teams in the intervention group compared to the control group. A low compliance with the intervention program was an important limitation with the approach used.

3. An eight-month injury registration among young female football players indicates that the total injury risk was the same when playing on artificial turf as on natural grass. However, although this was the largest study to date, study power was still limited, and risk differences for specific injury types between grass and artificial turf could not be ruled out.

4. About 70% of the young female players reported to have had at least one previous injury to the ankle, knee, hamstring or groin during their sports careers. A history of previous injury and reduced function at baseline were significant risk factors for new injuries to the same region during the season.

5. A perceived mastery climate and a high level of life stress were significantly associated with new injuries in a cohort of young female football players. A positive motivational climate in a team is desirable to help players with a high perception of life stress, and emphasis on negative perfectionism among players should be avoided.

Future research

In female football, injury incidence and patterns are now well documented. This is not the case for injury prevention measures, nor injury risk factors and mechanisms, although such information is essential in developing effective prevention programs.

Throughout the PhD period, several questions have arisen which should lead to new studies in (female) football:

- As football has become a year-round sport with activities on different turf types including tournament play during winter time and pre-season preparation, any registration of football injuries in the future should therefore not be limited to the competitive season, but include the whole year.
- An increased effort should be made to address studies assessing modifiable injury risk factors. These studies should preferably be conducted as multifactorial approaches, concomitant with a sufficient sample size to ensure that causal relationships can be detected.
- Player skills and physical fitness levels will be of interest to evaluate in an injury risk factor analysis, both as separate risk factors and as covariates. However, such an approach requires injury and exposure registration on the individual level.
- An effort should be made to gain continuous and detailed knowledge of the injury risk in both female and male football on artificial turf on for example the influence of the shoe-surface relation, turf conditions and turf generations to injury risk.
- An interesting study will be to validate a shorter version of the risk factor questionnaire we used in Paper IV in order to increase sensitivity in identifying players at risk for lower limb injuries.
- Further observational studies among young and older players are needed to extend the relationship between psychological player characteristics and injury risk.
- Non-contact mechanisms of injury in women's football needs to be investigated to provide a better understanding of the risk factors involved and to develop preventive exercises. The underlying mechanisms to alter lower-extremity kinematics so as to decrease lower limb injury risk are still not consistently assessed.

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Errata

Papers 4 and 5

Since submission to the doctoral committee, Paper 4 has been accepted for publication to American Journal of Sports Medicine in its original form. The Journal has substituted the term "football" with "soccer" throughout the paper.

Paper 5 has been accepted for publication in a revised form to Scandinavian Journal of Medicine in Sciences and Sports. Minor changes have been made to the methods, results and discussion of the paper version presented in this thesis.

In both papers, the following sentence from the result chapter has been changed: "Of the 330 acute injuries included, 83 (25%) were re-injuries" to "70 (21%)".

These mistypes have been changed as followed:

Page 4:	"NAIRS classifies injuries as minor (0-7 days absence)" has been changed to " …. (1-7 days absence)"
Page 24:	Table 6. Kucera 2005: "ca. 550" players included has been changed to "1483 players".
Page 45:	"… ICC=0.06, IF=0.8" has been changed to "ICC=0.06, IF=1.8".
Page 56:	The conclusion for Paper I has been changed from "The exercise prescription of the "11" and compliance with the program were most likely insufficient to result in measurable performance enhancements" to "The exercise prescription of the "11" was most likely insufficient to result in measurable results".

Appendix

Papers I-V

Paper I

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Performance aspects of an injury prevention program: a ten-week intervention in adolescent female football players

K. Steffen, H. M. Bakka, G. Myklebust, R. Bahr

Department of Sports Medicine, Oslo Sports Trauma Research Center, Norwegian School of Sport Sciences, Oslo, Norway
Corresponding author: Kathrin Steffen, Department of Sports Medicine, Oslo Sports Trauma Research Center, Norwegian School of Sport Sciences, P.O. Box 4014 Ullevål Stadion, 0806 Oslo, Norway. Fax: +47 23 26 23 07, E-mail: kathrin.steffen@nih.no

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The injury rate in football is high, and effective injury prevention methods are needed. An exercise program, the "11," has been designed to prevent the most common injury types in football. However, the effect of such a program on performance is not known. The aim of this randomized-controlled trial was to investigate the effect of the "11" on performance after a 10-week training period. Thirty-four adolescent female football players were randomly assigned to either an intervention ($n = 18$) or a control group ($n = 16$). The "11" is a 15-min program consisting of ten exercises for core stability, lower extremity strength, balance and agility. Performance tests included isokinetic and isometric strength protocols for the quadriceps and hamstrings, isometric hip adduction and abduction strength, vertical jump tests, sprint running and soccer skill tests. There was no difference between the intervention and control groups in the change in performance from the pre- to post-test for any of the tests used. In conclusion, no effect was observed on a series of performance tests in a group of adolescent female football players using the "11" as a structured warm-up program.

Background

Football is probably the most popular sport worldwide, with a growing interest and an increasing number of female players in particular (Norwegian Football Association, 2005). It is a contact sport and challenges physical fitness by requiring a variety of skills at different intensities. Running is the predominant activity, and explosive efforts during sprints, duels, jumps and kicks are important performance factors, requiring maximal strength and anaerobic power of the neuromuscular system (Wisløff et al., 1998; Cometti et al., 2001; Reilly & Gilbourne, 2003; Hoff & Helgerud, 2004).

Unfortunately, the game is associated with a high risk of injuries, which results in significant costs for the public health system (de Loes et al., 2000) and may even cause long-term disability for the injured player (Lohmander et al., 2004; von Porat et al., 2004; Myklebust & Bahr, 2005). Serious knee injuries, such as anterior cruciate ligament injuries, are of particular concern in female team sports (Powell & Barber-Foss, 2000; Myklebust et al., 2003; Agel et al., 2005; Olsen et al., 2005). Consequently, there is every reason to emphasize the prevention of injuries in football, and to develop and implement prevention programs for young players as early in their career as possible.

Several programs have successfully incorporated one or more exercise components, including plyometrics, strength, neuromuscular training, running and cutting movement patterns, to prevent injuries in female (Hewett et al., 1999; Heidt et al., 2000; Myklebust et al., 2003; Mandelbaum et al., 2005; Olsen et al., 2005) and male athletes (Askling et al., 2003). However, compliance is a concern (Myklebust et al., 2003), and it may be difficult to motivate coaches and players to follow such exercise programs merely to prevent injuries, unless there is a direct effect performance benefit as well.

Exercises used in prevention protocols have also been shown to have performance effects among male football players, such as increased strength (Askling et al., 2003; Mjølsnes et al., 2004). Core stability exercises may improve technical skills and total awareness of the game (Holm et al., 2004; Leetun et al., 2004; Paterno et al., 2004). Comprehensive neuromuscular training programs that combine plyometrics, core strengthening, balance, resistance or speed/agility training may improve several measures of performance concomitantly and at the same time improve biomechanical measures related to lower extremity injury risk (Hewett et al., 2004; Paterno et al., 2004; Myer et al., 2005; Myer et al., 2006b).

In football, the "11" has recently been developed by an expert group convened by FIFA (F-MARC, 2005) as a structured warm-up program targeting the most common injury types in football, i.e. ankle and knee sprains, groin and hamstring strains. To explore the potential for combining injury prevention training with performance, the aim of this randomized-controlled study was to assess whether the "11" can improve performance in a group of 16–18-year-old female football players.

Materials and methods

Study population

The study was conducted during the second half of the 2004 football season, and adolescent female football players from two elite sport high schools in Oslo, Norway, were invited. Before the start of the investigation, the 36 players available received written and oral information about the study, and it was emphasized that participation in the "11" program was voluntary. Written consent was obtained. The players were screened for injuries using a questionnaire at the start of the study, and they had to be uninjured to be included. Two players had to be excluded because of injury. This resulted in a total of 34 players, who, stratified by school, were randomized individually to an intervention group (IG, $n = 18$) and a control group (CG, $n = 16$). The participants were competitive players with 13.3 [standard deviation (SD) 2.1] hours of football activities per week and had been involved in organized football for 10 (1.5) years. The players were aged 16–18 years (17.1 $\pm$ 0.8). The study was approved by the Regional Committee for Research Ethics.

The intervention program

The lower limb injury prevention program, the "11," was designed as a warm-up program. The exercises were chosen based on previous research on injury prevention and established principles for rehabilitation of groin, hamstrings, knee and ankle injuries (F-MARC, 2005). The 15-min program includes 10 exercises focusing on core stability, neuromuscular control, eccentric hamstrings strength and agility (Table 1). The 11th component, a focus on fair play, was not emphasized in the present study. The "11" was introduced to the players in the IG by a physical therapist, and they were provided with balance mats. The intervention program was to be carried out three times a week during football training at school. The players in the CG warmed up as usual, with jogging and ball-based exercises. More than 90% of the intervention sessions were supervised by the project coordinator. Player participation in all training sessions, as well as in the "11" for the IG in particular, was recorded throughout the study period.

Performance tests

Before the start of the intervention period and 1 week after the end of the intervention, the players took part in a testing procedure to assess the performance effects of the "11." The testing took place at the Norwegian School of Sport Sciences and the Norwegian Olympic Training Center. The test battery included five test stations and was completed within 3–4 h. The tests were conducted in the same order for each player for the pre- and the post-tests. One week before the pre-test, all players participated in a test run to familiarize themselves with the testing procedures. The test run and the pre- and post-tests were led by the same experienced lab personnel. The shoe type used by the players was recorded to ensure that the same equipment was used on both test days.

Lower extremity isokinetic and isometric torque

The strength testing protocol, also used by Raastad and Hallén (2000), consisted of tests for hamstring and quadriceps muscle function, including concentric, eccentric and isometric tests (REV9000, Technogym®, Gambettola, Italy). Only the dominant leg was tested. The players warmed up for 5 min on a bicycle with an intensity of 70–100 W. When the players underwent the test run, the dynamometer position, seat position and attachment arm length were recorded to ensure test replication. Straps were used to minimize movements of the torso and the thigh segment of the tested extremity. The arms were held across the chest. The hip angle was 90°. The axis of rotation of the dynamometer was aligned with the knee joint, and the angular movement of the knee joint was 90°.

Concentric isokinetic quadriceps and hamstring torques were measured at a test angular velocity of 60 and 240°/s, while eccentric isokinetic torque was tested at 60°/s only. After four warm-up repetitions, the players were instructed to perform three maximal concentric and four maximal eccentric

Table 1. The "11". Exercises and intensities of the structured warm-up program used (F-MARC, 2005)

Exercises	Intensities
Core stability	
The bench (1)	15 s × 4 repetitions
Sideways bench (2)	15 s × 2 repetitions on each side
Balance	
Cross-country skiing (3)	15 s × 2 repetitions on each leg
Chest pass in single-leg stance (4)	15 s × 3 repetitions on each leg
Forward bend in single-leg stance (5)	15 s × 3 repetitions on each leg
Figure of eights in single-leg stance (6)	15 s × 3 repetitions on each leg
Plyometrics	
Jumps over a line (sideways, forwards-backwards) (7)	15 jumps of each type
Zigzag shuffle (forwards and backwards) (8)	2 repetitions in each direction (20 m)
Bounding (9)	10–15 jumps × 3 repetitions (20 m)
Strength	
Nordic hamstrings (10)	5 repetitions

contractions for both hamstring and quadriceps at each angular velocity. There was a rest period of 1 min between the different angular velocities. The quadriceps:hamstring ratio (Q:H ratio) was calculated for all angular velocities for concentric torque, and for concentric quadriceps torque vs eccentric hamstring torque at 60°/s. The isometric quadriceps and hamstring torques were measured at 30°, 60° and 90° of knee flexion. The players performed a 5-s maximal contraction at each knee flexion angle. Between two contractions at the same angle, the players had a 10-s pause, while they were given a 20-s rest between contractions at different angles. Strength was reported as the peak torque recorded (N m), and the best of three concentric, four eccentric and two isometric repetitions were used in the data analysis.

Isometric hip strength

Before the isometric strength tests for hip abductors and adductors, the players warmed up for about 5 min using a bicycle at an intensity of 70–100 W. The isometric strength of the adductor and abductor muscles was tested with a hand-held dynamometer (Hydraulic Push-Pull Dynamometer, Baseline® Evaluation Instruments, White Plains, New York, USA), similar to Krause et al. (2007). The tests were conducted with the players lying in a supine position on a bench. For the adductor muscles, tests were conducted with the knee in extended and flexed positions. When testing for adduction strength with the leg extended, the dynamometer was positioned 5 cm proximal to the medial ankle malleolus, while it was placed 5 cm proximal to the joint line of the knee on the medial side for testing in the flexed position. Isometric abduction was measured with the leg in the extended position only. The dynamometer was positioned 5 cm proximal to the lateral ankle malleolus. The arms were held across the chest 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. The highest value for each of the three tests was registered. The dominant leg for each player was recorded in order to analyze the values for the kicking and standing foot, respectively.

Jumping ability

Three different types of jump tests were performed on a force platform (AMTI, LG6-4-1, Watertown, Massachusetts, USA). As in a study of Wisløff et al. (2004), jumping height was determined as the center of mass displacement calculated from force development and player body mass, as measured on the force platform.

The starting position for the countermovement jump test was in the upright position, equal weight-bearing, feet at hip width and the players holding their hands on the iliac crest. The players bent their knees to 90° of flexion and in one continuous movement, without stopping at the lowest position, they immediately started their upward motion to jump as high as possible. The best of three attempts was used for the analysis. A vertical drop jump test followed immediately after. The players were standing on a box, 30 cm high, with their feet positioned at hip width. They were instructed to drop down from the box and immediately perform a maximum vertical jump while using their arms actively. The highest value of three attempts was recorded. Additionally, a 15 s continuous rebound jump test was performed on a Bosco jump mat (Ergojump, Globus Italia, Codogne, Italy). The players held their hands on the iliac crest, bending their knees to 90° of flexion, and jumped continuously on both legs for 15 s.

Video analysis

Based on the study by McLean et al. (2005), a digital video camera (30 Hz) secured to a tripod was placed 3 m on the opposing site of the force plate during the jumping tests. Two dimension frontal plane knee angles were calculated for each movement trial (countermovement jump and vertical drop jump), from which peak angles were obtained using a software program (NEAT, NEAT Visions Inc., Palm Beach Gardens, FL, USA). The mean angles of three attempts (right+left leg divided by two) were chosen for analysis.

Forty meter single sprint

The sprint test, a standard test for assessing football players maximum speed (Cometti et al., 2001), was performed on an indoor track. The test was recorded with infrared photocells connected to a digital timing devise system. The players warmed up for 10 min including sprints at submaximal intensity. The players performed two 40 m trials, separated by a 3 min recovery period. The best attempt was used for the analysis. The players started from a standing position, and the timing system was triggered as soon as they left the starting mat. Sprinting times were recorded to a resolution of 0.01 s.

Speed dribbling

An indoor hall with synthetic floor was used for the football tests. Five official balls (Roteiro Matchball Euro 2004, Adidas©, Herzogenaurach, Germany, size 5) were calibrated for air pressure (0.8 kg/cm^2) for every fifth subject. After warming up with ball-based exercises, the players performed a 20 m shuttle run both with and without a ball aimed to assess coordinated dribbling under time pressure and speed. The test was based on a straight dribbling test developed by Reilly and Holmes (1983), where five cones were placed in a straight line 2.80, 4.80, 6, 8 and 10 m from the start line (perpendicular to the line). The players were instructed to dribble around alternate obstacles until the fifth cone was circled, and then return through the course in a similar fashion as fast as they could. Starting from an upright position, the test was completed when the player, in control of the ball, passed through a gate with electronic timers. Two successfully completed trials with and two without a ball were recorded, and the best result for each test was chosen for analysis. The infrared photocells, connected to a stop watch, were triggered as soon as the players left the starting mat and stopped again when they passed the gate. All times were recorded to a resolution of 0.01 s.

Shooting distance

From the speed-dribbling test, the players went straight to the distance shooting test. No further warm-up than a few long kicks was therefore required. The shooting test allowed assessment of shooting power over a long distance from a dead ball (Rösch et al., 2000). After a free run-up, the players kicked the ball from its dead position with their dominant leg as far as possible. The shot was successful when the ball landed in a pre-defined 23°-angle sector. The best of three attempts was measured in 10 cm units.

Statistical methods

The primary hypothesis, that there would be a difference between groups in the change in performance from pre- to post-tests, was analyzed using unpaired t-tests. The results from pre- and post-tests are reported as means with SD, while the changes within the IGs and CGs from pre- to post-tests are given as means with a 95% confidence interval. An intention-to-treat analysis was performed including all players who completed the pre- and post-tests, as well as a per-protocol analysis restricted to players who participated in the pre- and post-tests and completed more than 20 training sessions with the "11." The best result obtained in each of the performance tests was used in the statistical analysis. The level of significance was chosen to be $\alpha = 0.05$, and all tests were two-tailed.

Results

Of the 34 players included in the study (IG, $n = 18$ and CG, $n = 16$), one player from the IG quit her football career midway through the study. Additionally, two players from the CG were excluded: one was injured and the other withdrew before the start of the training period for unknown reasons. Thus, the final sample consisted of 17 players in the IG and 14 in the CG. There were no significant differences between the two groups in any of the results on the pre-tests.

The IG completed a maximum of 30 training sessions of the "11" during the 10-week intervention period, with a mean completion of 22 ± 10 sessions (range 0–29). Twelve of the 17 players in the IG completed ≥ 20 training sessions with the "11." There was no difference in the total amount of football training between the intervention and CGs.

The results from the intention-to-treat analyses and per-protocol analyses were the same, and therefore, only the results of the intention-to-treat analysis are reported in detail (Table 2).

Lower extremity isokinetic and isometric torque

Maximal concentric, eccentric and isometric hamstring torques did not change from pre- to post-test within any of the groups, but within the CG there

Table 2. Results from the pre-test (mean ± SD) and change (Δ, mean ± 95% CI) from pre- to post-tests within the intervention and control groups, as well as between-group differences in the change from the pre- to the post-test (Δ*G*, mean ± 95% CI). Positive values denote an increase from pre- to post-tests (Δ) or a result in favor of the intervention group (Δ*G*).

	Intervention group ($n = 17$)		Control group ($n = 14$)		Between-group Δ*G* (95% CI)
	Pre-test	Δ	Pre-test	Δ	
Lower extremity isokinetic torque					
Q_{con} 60° s^{-1} (N m)	141.0 (17.3)	3.1 (−3.0 to 9.2)	142.3 (16.9)	1.6 (−4.3 to 7.5)	1.5 (−6.7 to 9.8)
Q_{ecc} 60° s^{-1} (N m)	186.8 (19.9)	4.1 (−6.3 to 14.4)	174.3 (37.9)	14.1 (−1.1 to 29.3)	−10.0 (−27.0 to 7.0)
Q_{con} 240° s^{-1} (N m)	99.4 (9.6)	−0.2 (−5.8 to 5.3)	97.5 (8.9)	0.9 (−5.2 to 7.1)	−1.2 (−9.15 to 6.7)
H_{con} 60° s^{-1} (N m)	85.8 (13.7)	−0.9 (−5.3 to 3.5)	91.5 (9.8)	−2.1 (−5.2 to 1.1)	1.2 (−4.2 to 6.6)
H_{ecc} 60° s^{-1} (N m)	104.5 (15.0)	−1.4 (−5.8 to 3.0)	106.5 (11.7)	−4.1 (−11.0 to 2.9)	2.7 (−4.9 to 10.2)
H_{con} 240° s^{-1} (N m)	75.7 (9.8)	1.1 (−2.5 to 4.6)	76.9 (9.1)	−1.0 (−6.2 to 4.2)	2.1 (−3.8 to 7.9)
Lower extremity isometric torque					
Q_{iso} 30° (N m)	99.6 (14.8)	1.9 (−3.5 to 7.3)	100.0 (11.8)	0.2 (−4.2 to 4.7)	1.6 (−5.3 to 8.6)
Q_{iso} 60° (N m)	165.5 (26.9)	4.1 (−4.2 to 12.4)	163.9 (19.2)	8.3 (−1.4 to 18.0)	−4.2 (−16.3 to 8.0)
Q_{iso} 90° (N m)	153.2 (22.3)	4.1 (−4.4 to 12.7)	150.1 (21.6)	16.4 (5.7 to 27.2)	−12.3 (−25.3 to 0.7)
H_{iso} 30° (N m)	88.1 (16.4)	3.8 (−4.0 to 11.6)	97.0 (14.3)	−1.5 (−9.0 to 5.9)	5.3 (−5.2 to 15.8)
H_{iso} 60° (N m)	80.4 (14.2)	4.7 (−1.3 to 10.8)	83.8 (15.2)	4.9 (−2.3 to 12 2)	−0.2 (−9.2 to 8.8)
H_{iso} 90° (N m)	69.6 (10.9)	−0.5 (−6.6 to 5.5)	67.4 (16.2)	0.6 (−5.2 to 6.5)	−1.1 (−9.3 to 7.0)
Ratio (Q:H)					
Q:H_{con} 60° s^{-1} (%)	61.0 (7.9)	−2.0 (−5.5 to 1.2)	64.8 (7.2)	−2.2 (−5.0 to 0.7)	0.2 (−4.3 to 4.7)
Q:H_{ecc} 60° s^{-1} (%)	56.3 (8.3)	−1.5 (−5.5 to 2.5)	62.9 (10.4)	−7.6 (−12.9 to −2.2)	6.1 (−0.2 to 12.4)
Q:H_{con} 240° s^{-1} (%)	76.5 (9.2)	1.1 (−3.1 to 5.4)	78.9 (5.5)	−0.8 (−6.5 to 4.8)	2.0 (−4.7 to 8.6)
Q_{con} 60° s^{-1}:H_{ecc} 60° s^{-1}(%)	1.4 (0.2)	0.1 (−0.1 to 0)	1.3 (0.2)	0.1 (−0.2 to 0.1)	0 (−0.2 to 0.1)
Isometric hip strength					
Kicking foot extended (kg)	15.5 (2.1)	0.6 (−0.2 to 1.5)	16.4 (2.2)	0.9 (−0.4 to 2.1)	−0.2 (−1.6 to 1.2)
Kicking foot flexed (kg)	16.8 (3.1)	0.4 (−1.2 to 2.0)	15.4 (2.1)	2.1 (0.5 to 3.8)	−1.7 (−4.0 to 0.5)
Standing foot (kg)	12.8 (1.6)	−1.8 (−3.0 to −0.6)	13.9 (1.6)	−2.0 (−3.1 to −0.9)	0.2 (−1.4 to 1.8)
Jumping ability					
Countermovement jump (cm)	27.9 (3.2)	−0.7 (−1.5 to 0)	27.9 (2.4)	−1.4 (−2.2 to −0.7)	0.6 (−0.4 to 1.6)
Vertical drop jump (cm)	31.7 (4.0)	−0.3 (−1.2 to 0.6)	32.4 (3.4)	−1.6 (−3.0 to −0.1)	1.3 (−0.2 to 2.9)
Rebound jump (cm)	23.3 (3.6)	−0.8 (−1.9 to 0.2)	22.9 (3.4)	−0.5 (−2.2 to 1.3)	−0.4 (−2.2 to 1.5)
Video analysis					
Countermovement jump (°)	175.9 (7.2)	−1.0 (−4.6 to 2.6)	176.8 (5.4)	−0.3 (−3.3 to 2.6)	0.6 (−3.9 to 5.2)
Vertical drop jump (°)	167.0 (7.3)	0.2 (−2.2 to 2.5)	167.6 (5.1)	0 (−4.2 to 4.3)	−0.1 (−4.5 to 4.2)
Single sprint					
40 m (s)	5.97 (0.25)	−0.04 (−0.2 to 0.11)	5.93 (0.26)	0.01 (−0.05 to 0.07)	0.03 (−0.06 to 0.11)
Football tests					
Dribbling without a ball (s)	5.65 (0.37)	−0.10 (−0.19 to −0.16)	5.52 (0.22)	−0.08 (−0.21 to 0.05)	−0.02 (−0.17 to 0.12)
Dribbling with a ball (s)	9.79 (0.85)	−0.68 (−1.10 to −0.26)	9.98 (0.82)	−0.71 (−1.11 to −0.32)	0.03 (−0.53 to 0.59)
Long distance kick (m)	35.1 (4.8)	−1.1 (−2.8 to 0.7)	36.2 (5.6)	−0.9 (−2.2 to 0.43)	−0.2 (−2.4 to 2.0)

Con, concentric; ecc, eccentric; iso, isometric; Q, quadriceps; H, hamstrings.

was a significant increase in isometric quadriceps torque at 90° ($P = 0.01$). However, no significant differences were observed between groups in the change from pre- to post-test for any of the hamstring or quadriceps strength tests. Consequently, there were no significant between-group differences in the quadriceps:hamstring ratio change. P-values for these 16 lower extremity strength variables ranged from 0.06 to 0.96.

Isometric hip strength

No between-group differences in the change from the pre- to the post-test were detected for any of the three tests ($P = 0.77$ for kicking foot extended, $P = 0.12$ for kicking foot flexed, $P = 0.82$ for standing foot).

Jumping ability

In the pre- and post-tests, the analysis showed comparable mean jumping performance values in the two groups for all three of the maximal jump tests. Consequently, there were no significant between-group differences in the change from the pre- to the post-tests observed ($P = 0.21$ for countermovement jump, $P = 0.08$ for vertical drop jump, $P = 0.68$ for rebound jump).

Video analysis

After the end of the intervention period, similar changes in stance phase valgus angles for countermovement jump and vertical drop jump were found in the intervention and the CGs. No between-group differences in the change were detected ($P = 0.77$ for countermovement jump, $P = 0.95$ for vertical drop jump).

Forty meter single sprint

The sprint times recorded did not differ from pre- to post-test within the IG (0.04 ± 0.03 s) or the CG (0.01 ± 0.03 s). There was no significant difference between the two groups in the change from the pre- to the post-test in the 40 m single sprint performance ($P = 0.53$).

Speed dribbling

In the straight dribble test (with the ball), both groups performed significantly better in the post-test than in the pre-test ($P = 0.003$ for the IG and $P = 0.002$ for the CG), but there were no significant differences between the two groups in the change ($P = 0.91$ with the ball, $P = 0.75$ without the ball).

Long-distance kick

In the pre- and post-test, the players in the intervention and CGs had comparable results in shooting distance, and there was no between-group difference in the change from the pre- to the post-test ($P = 0.88$).

Discussion

The main finding of this investigation was that no significant performance differences were observed in any of the variables tested between an IG using the injury prevention program and a CG warming up as usual. The most likely explanation is that the training volume and intensity for each of the exercises were too low to result in performance improvements. In addition, the test battery available may not have detected all potential improvements in performance.

If training protocols were designed to not just prevent injuries but also increase performance, combined performance and prevention training could be instituted with a higher potential for athlete compliance. However, in the present case, no increased performance was detected.

Low volume and intensity

Other studies show that successful injury prevention programs include exercise stimuli with a potential for improving sports performance (Hewett et al., 1999; Heidt et al., 2000; Askling et al., 2003; Paterno et al., 2004; Myer et al., 2005; Myer et al., 2006a). When comparing the "11" with these programs, there are essential differences in the content and structure, mainly the duration, the possibilities for variation of the involved exercises and the progression of intensity.

Myer et al. (2005) found that there were significant performance effects of a comprehensive neuromuscular training program for all training components, i.e. plyometrics, strength, core stability and speed training. Some of the exercises used in their program were similar to those composing the "11." However, each training session was performed intensively for 90 min three times a week compared with the 15-min bouts of the "11". Progression guidelines were also used for each of the exercise groups (Myer et al., 2005).

Other training programs, successfully combining performance aspects and injury prevention, were also designed to be carried out intensively over a short pre-season period, but with 60–90-min sessions three times weekly (Hewett et al., 1996, 1999; Heidt et al., 2000). Two randomized studies on strength training showed that a 10-week training program based on eccentric hamstring training effectively developed maximal eccentric hamstrings strength in well-trained football players (Askling et al., 2003; Mjølsnes et al., 2004). We found no strength increase in the IG, even if the same exercise was used.

In the current study, the exercises were used as a warm-up program, and we therefore limited the duration of the whole program to 15 min. This restricted the ability to increase the number of repetitions substantially and the progression of the training stimulus was clearly lower than e.g. Askling et al. (2003) or Mjølsnes et al. (2004). Low training intensity is also the most likely reason for the lack of change in varus–valgus angles in landing activities after the training period, a result that contrasts with that of other studies (Hewett et al., 1996; Myer et al., 2005; Myer et al., 2006b). Training volume, intensity and progression are key determinants for the outcome, and it appears that the current exercise prescription was insufficient.

Test battery

Even if the players appeared to increase their exercise capacity during the intervention period, e.g. they were clearly able to do more repetitions with a better quality of the hamstring, core stability and jumping exercises, the tests revealed no significant improvements. Although the test battery used was thought to be the best suited for assessing the effect of the program, the specificity of the tests available is not 100%.

There is a high degree of mode specificity for strength training, meaning that one will need a test that is very similar to the exercise being trained to fully detect a potential improvement (Svensson & Drust, 2005). Isokinetic strength tests do not reflect the movements of the limbs involved during sprinting, kicking a ball or jumping (Cometti et al., 2001). Wisløff et al. (1998) therefore suggested that tests using free weights will reflect the functional strength of the football player more accurately. Nevertheless, isokinetic testing is a safer and more reliable measure of strength in persons not familiar with free weight training (Svensson & Drust, 2005), and the only method available to test eccentric muscle performance. Also, a significant increase in eccentric hamstring torque has been detected using the same isokinetic test as the present (Mjølsnes et al., 2004). The measurements of 60 and 240°/s for the isokinetic tests were selected because these angular velocities cause little fatigue and have shown high test–retest reproducibility (Raastad & Hallén, 2000). We used the "functional" hamstring/quadriceps ratio, defined as the ratio of maximal eccentric hamstring torque relative to concentric quadriceps torque (H_{ecc}/Q_{con}), which was introduced by Aagaard et al. (1995). This ratio is thought to be relevant when focusing on the prevention of knee ligament as well as hamstring injuries. During knee joint movements, specifically during high levels of muscle force in knee extension, quadriceps contraction forces may result in anterior-directed shear of the tibia relative to the femur. The H_{ecc}/Q_{con} is thought to indicate the extent to which the hamstring muscles are capable of counteracting the anterior shear forces and, consequently, prevent the knee from ligament injury. In a similar way, it is assumed that it is the forces generated by concentric quadriceps muscle activity during maximal running that need to be counteracted by eccentric hamstring muscle action, at least when braking the forward swing of the lower leg during the final part of the swing phase and when hamstring strains are thought to occur (Bahr & Holme, 2003). Nevertheless, as no significant differences were observed for any of the isokinetic test variables, the results would be the same regardless of which ratio is used.

We tested isometric hip strength even if the "11" did not include any exercise specific for the adductor muscles. However, both core stabilization exercises and dynamic balance exercises could, to a certain extent, influence the adduction muscles (Akuthota & Nadler, 2004; Leetun et al., 2004). Isometric strength testing of hip adduction and abduction does not reflect the muscle recruitment pattern during football movement patterns. One might argue that the ability to demonstrate core stability should be tested in more physiologic positions. Dynamic testing of lower extremity alignment during a close kinetic chain activity e.g. single leg step-down may have been an appropriate supplement to the present performance test battery (Zeller et al, 2003).

Countermovement jumps and vertical drop jumps are standard tests to assess jumping ability in football players (Cometti et al., 2001). During the intervention period, the players appeared to perform the plyometric exercises with a higher intensity as they became familiar with them. Still, no significant improvement was seen in any of the tests for jumping ability compared with the CG. In part, this may reflect poor jumping technique during the testing, because many of the players struggled when tested. If the average values of the three best attempts for each player were used to minimize outliners, between-group results then became significantly different in favor of the IG for countermovement jump and vertical drop jump (data not shown).

The "11" did not contain any specific sprint exercises. However, because the thigh musculature, especially hamstrings strength, is of importance in sprint (Reynolds et al., 2001; Askling et al., 2003; Kraemer et al., 2003), increased strength could result in improved sprint times. This was not the case, but perhaps not surprising, considering that no effect on isokinetic or isometric hamstring torque was seen either.

One argument against focusing on injury prevention exercises in warm-up programs is that they may conflict with the development of technical skills. The purpose of including football tests in the test battery (speed dribbling and long-distance kick) was to assess this. In spite of spending less time with the ball, the players in the IG performed just as well on the test as the players in the CG.

Methodological issues

Calculations before the study using a power of 80% showed that a group difference of changes of at least 12 N m (eccentric hamstring torque) and 2.7 cm (jumping ability) was needed to detect a significant effect of the intervention program with 17 players in each group. However, the present results indicate that more than 310 players would have had to be included in each group to detect the observed differences in eccentric hamstrings strength with the observed standard deviation with 80% power at the 5% significance level.

The tests and intervention period were planned for the second half of the season, after the 7-week summer break, to achieve the greatest training intensity at school and to minimize out-of-school activities for the players. The post-tests were performed up to 4 weeks after the end of the competitive football season, and this may have negatively influenced the physical condition of the players on the test day. However, this applies to both groups and should not result in any bias between groups.

Conclusions

No significant effects were observed on different performance variables among adolescent female football players participating in a 10-week injury prevention program, the "11," compared with players who trained as usual.

Perspectives

Pre-season training contributes to the fitness level of players, and physically fitter players can compete at a higher level (Árnason et al., 2004; Hägglund et al., 2005). Higher levels of both strength and neuromuscular control may reduce injury risk and would be favorable in football by allowing more powerful sprints, jumps and duels (Wisløff et al., 1998; Leetun et al., 2004). The benefits of eccentric hamstrings training on injury risk (Askling et al., 2003; Árnason et al., 2007) and increasing strength (Askling et al., 2003; Mjølsnes et al., 2004) have been reported in three recent trials. Therefore, the potential role of systematic fitness and strength training as part of warm-up and football training should be evaluated. For future investigations, large-scale projects should be implemented in order to clarify the potential of injury-preventive exercises in performance and injury risk. However, it appears that the current exercise prescription was insufficient and that a more intense training stimulus is needed to increase fitness substantially. Even so, there is a limit to how much time teams and coaches are willing to spend on exercise programs to prevent injury. For youth and adolescent teams, who typically practice two to four times a week, asking them to spend a similar amount of time on injury prevention exercises is not realistic, even if the injury prevention program also were shown to improve football performance. In our opinion, to successfully implement injury prevention exercises in the regular training program of youth and adolescent football teams on a consistent basis, the duration of the program should not exceed 20 min per session, and preferably be designed to replace the ordinary warm-up exercises used by the team.

Key words: injury prevention, conditioning, strength, neuromuscular, plyometrics, warm-up, pre-season training.

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Preventing injuries in female youth football – a cluster-randomized controlled trial

K. Steffen, G. Myklebust, O. E. Olsen, I. Holme, R. Bahr

Department of Sports Medicine, Oslo Sports Trauma Research Center, Norwegian School of Sport Sciences, Oslo, Norway
Corresponding author: Kathrin Steffen, Department of Sports Medicine, Oslo Sports Trauma Research Center, Norwegian School of Sport Sciences, P.O. Box 4014 Ullevål Stadion, 0806 Oslo, Norway. Fax: 47 23 26 23 07, E-mail: kathrin.-steffen@nih.no

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A set of exercises – the "11" – have been selected to prevent football injuries. The purpose of this cluster-randomized controlled trial was to investigate the effect of the "11" on injury risk in female youth football. Teams were randomized to an intervention ($n = 59$ teams, 1091 players) or a control group ($n = 54$ teams, 1001 players). The intervention group was taught the "11," exercises for core stability, lower extremity strength, neuromuscular control and agility, to be used as a 15-min warm-up program for football training over an 8-month season. A total of 396 players (20%) sustained 483 injuries. No difference was observed in the overall injury rate between the intervention (3.6 injuries/1000 h, confidence interval (CI) 3.2–4.1) and control group (3.7, CI 3.2–4.1; RR = 1.0, CI 0.8–1.2; $P = 0.94$) nor in the incidence for any type of injury. During the first 4 months of the season, the training program was used during 60% of the football training sessions, but only 14 out of 58 intervention teams completed more than 20 prevention training sessions. In conclusion, we observed no effect of the injury prevention program on the injury rate, most likely because the compliance with the program was low.

The popularity of female football has increased worldwide during the last decades (Engström et al., 1991; Östenberg & Roos, 2000; Söderman et al., 2001; Emery et al., 2005; Faude et al., 2005), and in 2005 25% of the players in the Norwegian Football Association (NFF) were female (NFF, 2005). The injury incidence among elite and non-elite female players is reported to be similar to male football players, ranging from 12.6 to 24 injuries per 1000 match hours and from 1.2 to 7 per 1000 training hours (Engström et al., 1991; Östenberg & Roos, 2000; Faude et al., 2005; Giza et al., 2005). However, two recent cohort studies have reported somewhat lower figures among adolescent female football players: 8.9–9.1 and 1.5–2.6 per 1000 match and training hours, respectively (Söderman et al., 2001; Emery et al., 2005).

The most common injury locations in female football players are the knee (7–32%), ankle (9–31%) and thigh (6–22%) (Engström et al., 1991; Östenberg & Roos, 2000; Söderman et al., 2001; Junge et al., 2004a; Faude et al., 2005; Giza et al., 2005). The risk for serious knee injuries, such as anterior cruciate ligament (ACL) injuries, is a particular concern in female sports (Myklebust et al., 2003; Faude et al., 2005; Mandelbaum et al., 2005; Olsen et al., 2005; Silvers et al., 2005; Hewett et al., 2006), and after an ACL injury, there is a dramatic increase in the risk of early osteoarthrosis (von Porat et al., 2004; Myklebust & Bahr, 2005). In junior football, the ACL injury rate was reported to be five times higher for girls than for boys (Bjørdal et al., 1997; Powell & Barber-Foss, 2000), Thus, there is clearly a need to develop programs to prevent lower extremity injuries in football and implement these as early as possible. Studies from different sports have shown promising reductions in injury rates using training protocols incorporating one or more exercise component focusing on balance training, strength and/or agility (Caraffa et al., 1996; Heidt et al., 2000; Junge et al., 2002; Askling et al., 2003; Myklebust et al., 2003; Wedderkopp et al., 2003; Mandelbaum et al., 2005; Olsen et al., 2005). However, prospective randomized intervention studies are still needed to investigate the efficacy of training programs aimed to reduce injuries in football, especially among young female players. One such program – the "11" – has been developed recently by an expert group convened by Fédération Internationale de Football Association (FIFA) (F-MARC, 2005). The "11" was developed as a structured warm-up program targeting the most common injury types in football, i.e. ankle and knee sprains, groin and hamstring strains. The program was designed on the basis of previous research on injury prevention (Junge et al., 2002; Myklebust et al., 2003; Mjølsnes et al., 2004; Mandelbaum et al., 2005; Olsen et al., 2005) and established principles for rehabilitation of such injuries (F-MARC, 2005).

The purpose of this cluster-randomized controlled trial was to examine the effect of the "11," used as a warm-up exercise program to prevent injuries among young female football players.

Material and methods

Study population

All teams in the southeast regions of Norway that registered to participate in the Under-17 league system during the 2005 season were invited to take part in the study. Of 157 available teams, 113 teams (72%) with a total of 2100 players agreed to participate in the investigation (Fig. 1). The competitive season lasted from the end of April until mid-October, interrupted by a 7-week summer break without regular league matches, only invitational tournaments. The teams were also followed for 2 months of the pre-season period (March–April).

After recruitment of all teams into the study, these were block-randomized with four teams in each block into an intervention group and a control group. To reduce potential confounding, the teams were matched by region. All teams from one club were in the same treatment arm, and there were seven clubs included with two teams each. The statistician (I. H.) who conducted the randomization was not involved in the intervention, and recruitment was completed before randomization. The teams in the intervention group were given information about the prevention program, while the teams in the control group were asked to continue their warm-up and training as usual during the season. They were informed that they would receive the same injury prevention program as the intervention group during the subsequent season, provided the program was shown to prevent injuries.

Before the start of the pre-season, the players received written and oral information about the study, and it was emphasized that participation was voluntary. The study was approved by the Regional Committee for Research Ethics, and written consent was obtained. A player was entered in the study if she was registered by the team as participating in the U17 league system, which means that she had to be 16 years or younger. However, teams competing in the U17 league could apply for an exemption to use older players, if they did not have enough eligible players. The players were screened for injuries using a self-constructed questionnaire, and they had to be uninjured at the start of the study to be included.

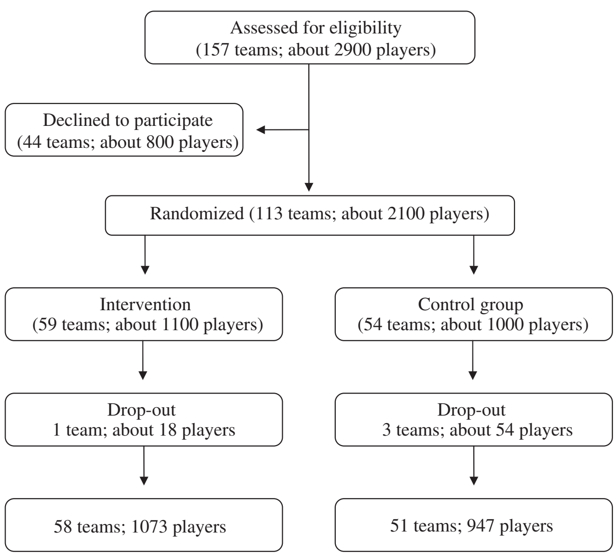

Fig. 1. Flow of teams and players through the study.

The intervention program

The intervention program – the "11" – includes 10 exercises focusing on core stability, balance, dynamic stabilization and eccentric hamstrings strength (F-MARC, 2005) (Table 1). The 11th component, fair play, was not included as part of the program tested in this study.

When introducing the program to the teams, the main focus was on performing the exercises properly. The players were encouraged to concentrate on the quality of their movements, and emphasis was placed on core stability, hip control and proper knee alignment to avoid excessive genu valgus in the static and dynamic balance exercises, as well as in landings from jumps. The coaches and players were instructed to watch each other closely during the training sessions and give continuous feed back.

The teams in the intervention group received 15 balance mats each (40 cm × 50 cm, 7 cm thick; Alusuisse Airex, Sins, Switzerland), which were not part of the original "11," Additionally, all coaches and players received a detailed brochure describing the intervention program, how the exercises should be performed properly, as well as common errors. After familiarization with the exercises, the program was planned to last about 20 min, including 5 min of jogging before starting the exercises. The coaches were asked to use the program every training session for 15 consecutive sessions and thereafter once a week during the rest of the season, replacing any warm-up routine normally used by the team.

The prevention program was introduced to the teams in the intervention group in the beginning of the pre-season, with guidance and surveillance by 26 instructors, mainly from the NFF, each of them responsible for two to three teams. The instructors had been introduced to the intervention program during a seminar, where they received theoretical and practical training in the program and were instructed in how to teach the exercises to the teams. The instructors visited the teams in the intervention group three times during the initial training period, with a booster visit immediately after the 7-week summer break to encourage the teams to continue using the training program. In addition, the first author (K. S.) was in regular contact with the coaches, i.e. by phone/mail and by site visits on the pitch. Implementation of the prevention program in the selected teams by the instructors took about $1\frac{1}{2}$ month.

At the first prevention training session, the coaches in the intervention group received a compliance form to record participation in the prevention program. Detailed information was requested on the duration of each session in minutes, and the number of attending players.

Injury and exposure registration

To monitor injuries and playing exposure, 18 physical therapists were recruited as injury recorders and assigned to the teams (typically five to seven teams each) during the period from March 1, through October 31, 2005. A seminar had been held for injury recorders to introduce them to the study aims and the injury registration system. All injuries were recorded that occurred after the first prevention training session had been completed by an intervention team, and from the same

Table 1. Exercises and repetitions of the "11" used as a structured warm-up program (F-MARC, 2005)

Exercises	Description	Repetitions
Core stability		
The bench (1)	Leaning on your elbows in the prone position, lift the upper body, hips and knees so that the body forms a straight line from the shoulder to the heels. Hold this position	15 s $\times$ 4 repetitions
Sideways bench (2)	Leaning on one elbow in the side position, lift top leg and hips until the shoulder, hip and top leg are in straight line and parallel to the ground. Hold this position	15 s $\times$ 2 repetitions on each side
Balance		
Cross-country skiing (3)	In single-leg stance, continuously bend and extend the knee of the supporting leg and swing the arms in rhythm	15 s $\times$ 2 repetitions on each leg
Chest pass in single-leg stance (4)	Partner exercise with both players in single-leg stance. Throw a ball back and forth	15 s $\times$ 3 repetitions on each leg
Forward bend in single-leg stance (5)	As (4). Before throwing back, touch the ball to the ground without putting weight on it	15 s $\times$ 3 repetitions on each leg
Figure-of-eights in single-leg stance (6)	As (4). Before throwing back, move the ball in a figure-eight through and around both legs	15 s $\times$ 3 repetitions on each leg
Plyometrics		
Line jumps (sideways, forwards-backwards) (7)	Two-leg jumps sideways over a line and forward-back as quickly as possible	15 jumps of each type
Zigzag shuffle (forwards and backwards) (8)	Shuffle sideways with a low center of mass to the first cone, turn so that the other shoulder points to the next cone and complete the zigzag course as fast as possible	2 repetitions in each direction (20 m)
Bounding (9)	Spring as high and far as possible off the supporting leg. Bring the knee of the trailing leg up as high as possible and the opposite arm in front of the body. Continuous bounding, switching legs on each take off	10–15 jumps $\times$ 3 repetitions (20 m)
Strength		
Nordic hamstrings (10)	Lower legs are held stable by a partner. Slowly lean forward keeping the upper body and hips straight while resisting the forward-falling motion by the hamstring muscles	5 repetitions

The single-leg balance exercises (4, 5 and 6) were done on a balance mat when the players were able to perform these exercises properly on stable ground.

date a team in the control group that was randomized to the same block. The coaches of each team were contacted by telephone and/or e-mail at least once a month to record all training and match activity, in addition to new injuries. Injured players were interviewed by the injury recorders to assess aspects of the injury based on a standardized injury questionnaire. The injury recorders were blinded to which group the teams and injured players belonged to. The information was registered using a web-based recording system.

In accordance with the consensus statement on injury definitions and data collection procedures (Fuller et al., 2006), an injury was registered if it caused the player to be unable to fully take part in the next match or training session ("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. Recurrent injuries were defined as an injury of the same type and the same site as an index injury and that occurred after a player's return to full participation from the index injury. In addition, the injury circumstances (contact vs non-contact), the location and the type of injury were recorded. Injuries were classified into three severity categories according to the length of absence from training sessions and matches until the player was fully fit to take part in all types of organized football play as follows: minor (1–7 days), moderate (8–21 days) and major (>21 days) (van Mechelen et al., 1992).

In almost all cases of moderate and major injuries, the players were seen in a medical center to diagnose the injury by clinical tests, imaging studies or surgery. In cases of minor injuries, the players were examined by a local physical therapist, the coach or not at all. None of the injured players was examined or treated by any of the authors or injury recorders involved in the study.

Data on match and training exposure were collected on a team basis. The overall match and training injury incidence was calculated as the number of injuries per 1000 player hours. To calculate match exposure, match playing time (in minutes) was multiplied by 11 and for training exposure, training time (in minutes) was multiplied by the monthly player attendance. A regular league match was played for 2×40 min, while a training session in most cases lasted for 90 min.

Additionally, information on any preventive training used in the control group, including their type and frequency, was obtained at the end of the season.

Outcome measures

The primary outcome variable was to compare the overall injury rate of the intervention with the control groups, after the first prevention training session in the intervention teams had been completed. Secondary effect variables were the proportion of injured players, the incidences of ankle, knee, groin, hamstrings and other injuries in both groups during the same study period.

Sample size and statistics

Because data on injury incidence in female youth team sports are limited, the sample size was based on data from Swedish female youth football (Söderman et al., 2001) and Danish and Norwegian youth team handball (Wedderkopp et al., 2003; Olsen et al., 2006), which was more assumed to be similar to youth football. From these studies, we estimated that 12% of the players would injure their knee or ankle during one season.

Similar to Olsen et al. (2005), we used one-way analysis of variance to estimate the intracluster correlation coefficient (ICC) to obtain estimates of the inflation factor for comparison with planned sample size. An ICC of 0.05 will give us an estimated inflation factor for cluster effects of 1.8. Owing to randomization by teams, a total of 900 players in each group would provide a power of 0.73 at the 5% significant level to detect a 40% reduction in the number of players with a knee or ankle injury. Our model was based on 120 teams with 18 players per team and a drop-out rate of 15%, i.e. a total of 1800 players.

The proportional difference in the frequency of injured players in the intervention group and the control group was analyzed by a χ^2-test. We used a Z-test and found 95% confidence intervals (CI) based on the Poisson model to compare the rate ratio (RR) of number of injuries between these two groups.

In addition to the intention-to-treat analysis, data are shown separately for teams in the intervention group who better complied with the program and teams who did less (subgroup analysis). Teams were considered to be more compliant if they carried out the prevention program for at least 20 sessions from their first instruction day through June. Results are presented as means with a 95% CI, unless otherwise noted. All tests were two tailed, and results significant with P-values below 0.05.

Results

Inclusion of teams and players

Figure 1 shows the flow of teams and players through the study. After the randomization had been completed, four teams declined to participate in the trial: one in the intervention group (did not have a coach) and three in the control group (withdrew from participation in the league system). The players ($n = 72$) in these teams were excluded from the study. The remaining players in the two groups were similar in their age [15.4 ± 0.8 years (SD) in both groups], age distribution and drop-out rates. Thus, the final sample consisted of 58 teams (1073 players) in the intervention group and 54 teams (947 players) in the control group (Table 2).

Table 2. Characteristics of participants

	Control ($n = 947$ players)	Intervention ($n = 1073$ players)
Age (years)		
13	11 (1.2)	5 (0.5)
14	77 (8.1)	127 (11.8)
15	425 (44.9)	462 (43.0)
16	377 (39.8)	432 (40.3)
17	57 (6.0)	47 (4.4)
Drop-outs	21 (2.2)	27 (2.5)

Values are numbers (%) of participants.

Compliance with the prevention program

The 58 teams in the intervention group performed the injury prevention program a total of 23 ± 9 (SD) times (range 2–42) during the course of the season. In comparison, the teams completed a total of 44 ± 16 sessions of football training (19–90) during the same period. In other words, the injury prevention program was used at 52% of all training sessions (10–100). During the first half of the season (from March through June), the injury prevention program was used in 14 ± 5 sessions (2–25) and after the summer break (from July through October) in 9 ± 5 sessions (0–21). This represents 60% (15–100) of the total number of training sessions before and 44% (0–100) of the training sessions after the summer break. For the prevention training sessions, the average player attendance was 67 ± 10% (51–91). The average time spent per session was 20 ± 4 min (12–32).

Two teams in the intervention group withdrew from the study during the summer break.

None of the control group teams reported to have performed structured exercises comparable with the prevention program throughout the season.

Injury characteristics

During the 8-month season, including the 2-month pre-season and the summer break, 396 (20%) of 2020 players sustained at least one injury. Of these players, 57 (3%) incurred two injuries and 15 (1%) three injuries, leading to a total of 483 injuries. Of these 483 injuries, 98 (20%) were re-injuries, and nine injuries (1.9%) were recurrences of previous injuries during the same season. The proportion of re-injured players in the intervention and control groups was 16% ($n = 32$ out of 204) vs 22% ($n = 43$ out of 192), respectively ($P = 0.22$). Most injuries were acute ($n = 421$, 87%) and most were located in the lower extremities ($n = 413$, 86%). The most common overuse injuries ($n = 62$, 13%) were anterior lower leg pain (29% of all overuse injuries) and knee pain (19%). With a proportion of 28%, an ankle sprain was the most common acute injury type.

In 42% of the 421 acute injury cases, the injury occurred in a non-contact playing situation, while 58% resulted from player-to-player contact. The proportion of contact injuries was higher during matches (86%, $n = 209$) than training (14%, $n = 33$) ($P < 0.001$).

Effect of the prevention program

The total exposure, as well as the match and training exposure, were similar for both groups (Table 3). No difference was observed in the proportion of injured players between the intervention group (19.0%, $n = 204$) and the control group (20.3%, $n = 192$) ($P = 0.50$). The mean age of injured players was 15.4 ± 0.8 years in the intervention and the control group, the same as in the total study population.

The intention-to-treat analysis revealed no difference in the overall injury incidence, nor in the acute match or training incidence between the intervention group and the control group (Table 4). The RR for the intervention vs the control group was 1.0 (CI 0.8–1.2, $P = 0.94$) for all injuries, 1.1 (0.9–1.3, $P = 0.54$) for acute match injuries and 0.7 (0.5–1.1, $P = 0.12$) for acute training injuries.

There were no significant differences between the groups in the distribution of type, location or severity of injuries. During the 8-month study period, nine ACL injuries occurred (0.07 injuries/1000 h, 95% CI 0.02–0.11), four in the intervention group and five in the control group (RR 0.8, 0.2–2.9, $P = 0.73$). An ankle sprain was the most common re-injury type in both groups. However, there was no significant difference between the groups in the number of re-injuries, including the number of recurrent ankle sprains. The RR for the intervention vs the control group for re-injuries was 0.9 (0.6–1.4, $P = 0.79$) and 1.0 (0.5–1.7, $P = 0.86$) for ankle sprain re-injuries.

In a sub-group analysis to determine whether compliance with the intervention program could have influenced the risk for injuries throughout the study period, the intervention group was divided into two sub-groups: those who performed at least 20 prevention training sessions (compliant), and those who completed <20 sessions (non-compliant). However, the analysis revealed no difference in the injury incidence of overall and acute injuries between these two sub-groups, or between the compliant sub-group and the control group (Table 4).

Table 3. Exposure data (hours) for the teams

No of teams	Control ($n = 947$ players)	Intervention ($n = 1073$ players)			Total ($n = 2020$ players)
	51	All	Compliant	Non-compliant	109
		58	14	44	
Match	19 856	20 731	5371	15 360	40 587
Training	45 869	45 692	13 722	31 970	91 561
Total	65 725	66 423	19 093	47 330	132 148

Discussion

The main finding of this investigation on young female football players was that we could not detect any differences in injury rates between teams in the intervention group, who were asked to use a structured warm-up program, and teams in the control group, who were told to warm up as usual with jogging and ball-based exercises. The most likely explanation is that the compliance of the teams and players in the intervention group was insufficient to produce the necessary training effects to reduce injury risk. The average intervention team only participated in about 15 prevention training sessions during the first half of the season, which includes the pre-season and the first half of the competitive season.

The present findings cannot directly be compared with other injury prevention studies from football, which have shown (Caraffa et al., 1996; Heidt et al., 2000; Junge et al., 2002; Mandelbaum et al., 2005) or failed to detect (Söderman et al., 2000) a reduction in injury rates. However, these studies differ in several aspects from the present study. Some used ACL injuries alone as the outcome of interest (Caraffa et al., 1996; Mandelbaum et al., 2005), and some used all-male (Caraffa et al., 1996; Junge et al., 2002) or professional players (Caraffa et al., 1996; Söderman et al., 2000) as their study population.

Compliance with the prevention program

Considerable efforts were made to motivate the intervention teams to include the exercise program as a standard part of their training program. Instructors visited the teams three times during training at the start of the study and again after the summer break, and the teams received balance mats and a brochure detailing the intervention program. Despite this, the intervention teams included the injury prevention program in only 60% of their training sessions during the first half of the season, and only about one quarter of the teams had completed more than 20 prevention training sessions before the summer break. In addition, only two-thirds of the players on these teams participated in these sessions on the average, which means that the average player only completed approximately 15 prevention training sessions. As shown by the sub-group analysis, this amount of prevention training seems to be ineffective in reducing injury risk among young female football players.

The compliance was considerably lower than that reported by Olsen et al. (2005) in their study on youth team handball, where a similar exercise program developed for youth team handball led to an impressive reduction in lower extremity injury risk. In a non-randomized study in senior elite team

Table 4. Number and incidence of injuries in various categories

	Intention-to-treat analysis					Sub-group analysis					
	Control ($n = 51$ teams)		Intervention ($n = 58$ teams)			Compliant ($n = 14$ teams)			Non-compliant ($n = 44$ teams)		
	Injuries	Incidence	Injuries	Incidence	Rate ratio (INT vs CON)	Injuries	Incidence	Rate ratio (COM vs CON)	Injuries	Incidence	Rate ratio (COM vs N-COM)
All injuries	241	3.7 (3.2–4.1)	242	3.6 (3.2–4.1)	1.0 (0.8–1.2)	64	3.4 (2.5–4.2)	0.9 (0.7–1.2)	178	3.8 (3.2–4.3)	0.9 (0.7–1.2)
Overuse	31	0.5 (0.3–0.6)	31	0.5 (0.3–0.6)	0.9 (0.6–1.7)	11	0.6 (0.2–0.9)	1.2 (0.6–2.4)	20	0.4 (0.2–0.6)	1.4 (0.7–2.8)
All acute injuries	210	3.2 (2.8–3.6)	211	3.2 (2.7–3.6)	1.0 (0.8–1.2)	53	2.8 (2.0–3.5)	0.9 (0.6–1.2)	158	3.3 (2.8–3.9)	0.8 (0.6–1.1)
Match	151	7.6 (6.4–8.8)	169	8.2 (6.9–9.4)	1.1 (0.9–1.3)	42	7.8 (5.5–10.2)	1.0 (0.7–1.4)	127	8.3 (6.8–9.7)	0.9 (0.7–1.3)
Training	59	1.3 (1.0–1.6)	42	0.9 (0.6–1.2)	0.7 (0.5–1.1)	11	0.8 (0.3–1.3)	0.6 (0.3–1.2)	31	1.0 (0.6–1.3)	0.8 (0.4–1.6)
Body location											
Upper body	37	0.6 (0.4–0.7)	30	0.5 (0.3–0.6)	0.8 (0.5–1.3)	4	0.1 (0–0.2)	–*	26	0.5 (0.3–0.8)	–*
Lower body	173	2.6 (2.2–3.0)	181	2.7 (2.3–3.1)	1.0 (0.8–1.3)	49	2.6 (1.8–3.3)	1.0 (0.7–1.3)	132	2.8 (2.3–3.3)	0.9 (0.7–1.3)
Groin	14	0.2 (0.1–0.3)	6	0.1 (0–0.2)	0.4 (0.2–1.1)	0	–*	–*	6	0.1 (0–0.2)	–*
Thigh	28	0.4 (0.3–0.6)	35	0.5 (0.4–0.7)	1.2 (0.8–2.0)	13	0.7 (0.3–1.1)	1.6 (0.8–3.1)	23	0.5 (0.3–0.7)	1.4 (0.7–2.8)
Knee	30	0.5 (0.3–0.6)	37	0.6 (0.4–0.7)	1.2 (0.8–2.0)	5	0.3 (0–0.5)	0.6 (0.2–1.5)	32	0.7 (0.4–0.9)	0.4 (0.2–1.0)
Ankle	74	1.1 (0.9–1.4)	79	1.2 (0.9–1.5)	1.1 (0.8–1.5)	24	1.3 (0.8–1.8)	1.1 (0.7–1.7)	55	1.2 (0.9–1.5)	1.1 (0.7–1.7)
Injury type											
Contusion	54	0.8 (0.6–1.0)	54	0.8 (0.6–1.0)	1.0 (0.7–1.4)	15	0.8 (0.4–1.2)	1.0 (0.5–1.7)	39	0.8 (0.6–1.1)	1.0 (0.5–1.7)
Sprain	84	1.3 (1.0–1.6)	89	1.3 (1.1–1.6)	1.1 (0.8–1.4)	22	1.2 (0.7–1.6)	0.9 (0.6–1.4)	67	1.4 (1.1–1.8)	0.8 (0.5–1.3)
Strain	42	0.6 (0.4–0.8)	45	0.7 (0.5–0.9)	1.1 (0.7–1.6)	14	0.7 (0.3–1.1)	1.1 (0.6–2.1)	31	0.7 (0.4–0.9)	1.1 (0.6–2.1)
Other	29	0.4 (0.3–0.6)	23	0.4 (0.2–0.5)	0.8 (0.5–1.4)	2	0.1 (0–0.1)	–*	21	0.4 (0.3–0.6)	–*
Re-injuries	43	0.7 (0.5–0.8)	41	0.6 (0.4–0.8)	0.9 (0.6–1.4)	9	0.5 (0.2–0.8)	0.7 (0.4–1.5)	32	0.7 (0.4–0.9)	0.7 (0.3–1.5)
Ankle sprains	23	0.3 (0.2–0.5)	22	0.3 (0.2–0.5)	1.0 (0.5–1.7)	6	0.3 (0.1–0.6)	0.9 (0.4–2.2)	16	0.3 (0.2–0.5)	0.9 (0.4–2.4)
Contact	124	1.9 (1.6–2.2)	118	1.8 (1.5–2.1)	0.9 (0.7–1.2)	33	1.7 (1.1–2.3)	0.9 (0.6–1.3)	85	1.8 (1.4–2.2)	1.0 (0.6–1.4)
Non-contact	86	1.3 (1.0–1.5)	93	1.4 (1.1–1.7)	1.1 (0.8–1.5)	20	1.0 (0.6–1.5)	0.8 (0.5–1.3)	73	1.5 (1.2–1.9)	0.7 (0.4–1.1)
Time loss (days)											
1–7	82	1.3 (1.0–1.5)	102	1.5 (1.2–1.8)	1.2 (0.9–1.6)	28	1.5 (0.9–2.0)	1.2 (0.8–1.8)	74	1.6 (1.2–1.9)	0.9 (0.6–1.4)
8–21	69	1.1 (0.8–1.3)	61	0.9 (0.7–1.1)	0.9 (0.6–1.2)	15	0.8 (0.4–1.2)	0.7 (0.4–1.3)	46	1.0 (0.7–1.3)	0.8 (0.5–1.4)
>21	59	0.9 (0.7–1.1)	48	0.7 (0.5–0.9)	0.8 (0.6–1.2)	10	0.5 (0.2–0.8)	0.6 (0.3–1.4)	38	0.8 (0.5–1.1)	0.7 (0.3–1.3)

*Owing to small numbers statistics were not computed.

The incidence is reported per 1000 h of exposure with 95% CI. Rate ratios are shown with 95% CI for intention-to-treat analyses between control (CON) and intervention (INT) teams, and for sub-group analyses between compliant (COM) teams and control teams, as well as between compliant and non-compliant (N-COM) teams.

CI, confidence interval.

handball, which examined the effect of a program developed to prevent ACL injuries, Myklebust et al. (2003) also observed poor compliance, as low as 28%. Similar to the present study, their study did not show any overall effect on injury rate, but in contrast to the present study a sub-group analysis revealed that the injury risk was significantly lower in players who had followed the prevention program. With the exception of these three studies, other intervention studies (Caraffa et al., 1996; Heidt et al., 2000; Junge et al., 2002; Askling et al., 2003; Mandelbaum et al., 2005) have not reported individual or team compliance in a way that makes it possible to compare between studies.

When attempting wide-scale implementation of preventive programs, it may be difficult to know how likely it is that the intervention will be adopted (Finch, 2006). The low compliance observed in the current study probably results from a number of factors. The pre-season preparation period for these teams was relatively short, as was the competitive season. Also, during midseason there was a 7-week summer break (school holidays), when few of the teams had organized training, but participated in tournaments. Also, matches were generally scheduled on weekdays, which further limited the time available for training, because the exercise program was generally not used to warm up for games. In the youth team handball study (Olsen et al., 2005), teams played their matches during the weekend, played a longer winter season with only a 2-week Christmas break midseason and used the injury prevention exercises up to three times a week during the season (Olsen OE, personal communication, 2006). In contrast, during the competitive season, many of the teams in the present investigation often trained only once or twice weekly. As a consequence of these factors, the ability to include preventive training sessions on a consistent basis may have been limited. It is possible that program implementation would be easier in teams who train more intensively, with more than three training sessions each week.

Previous authors have emphasized the importance of being focused and providing continuous feedback when training neuromuscular control (Myklebust et al., 2003; Hewett et al., 2005; Olsen et al., 2005), because balance exercises should be performed properly with a stable core and focus on the "knee-over-toe position" to achieve the desired training effects. Söderman et al. (2000) showed that home-based balance training did not have any effect on injury rates in female football players. In contrast, in the study by Myklebust et al. (2003) physical therapists were recruited to improve compliance and training quality by supervising training sessions regularly. Unfortunately, although proper skills and feedback by coaches and team mates were emphasized by the instructors during the implementation and follow-up visits, no quantifiable information could be obtained on the quality of exercise performance during the prevention sessions.

Contamination from the intervention to the control groups is a relevant issue in intervention trials such as this. However, our results show that there was no contamination in the control group. Instead, the challenge was in motivating the intervention teams to do the exercises as prescribed. At the end of the season, we made phone calls to all the coaches in the control group to ask them about their warm-up exercises and training routines. None of these teams performed structured exercises similar to the "11," and contamination is therefore not thought to have biased our results.

Content and structure of the prevention program

The exercises comprising the "11" represent evidence-based rehabilitation exercises for lower limb injuries (F-MARC, 2005) and key exercises from other effective injury prevention programs. However, in contrast to other prevention programs, the present exercise prescription did not provide the possibility for variation and progression. The ACL injury prevention program of Caraffa et al. (1996) and Myklebust et al. (2003) included a five-step progression from simple to more challenging within each of the balance and jump-landing exercises used. The lower limb injury prevention program of Olsen et al. (2005) consisted of four groups of varied exercises with progression guidelines within each category, structured jogging, technique, neuromuscular and strength training. Also, both the Myklebust program and the Olsen program included exercises where the athlete was perturbed during single-leg balance training, representing an additional challenge to the ability to maintain a stable core and proper alignment. In elite male football, hamstrings strength was trained three times weekly with a gradually increasing intensity over a 10-week period to increase strength successfully (Askling et al., 2003; Mjølsnes et al., 2004) and reduce strain injuries (Askling et al., 2003; Árnason et al., 2007). Thus, the current program contrasts with those used in these studies in that all of the 10 exercises were to be carried out during every 15-min training session, generally without progression or variation. This may have resulted in reduced motivation among coaches and players. Because training volume and intensity are key determinants for training outcome, the effectiveness of the current program might be improved by fewer exercises with more repetitions each training session to allow progression and higher intensities. In a separate study, we could not detect any effect on a range of performance tests in a group of adolescent female football players who used the "11" as a structured warm-up program for a 10-week period (Steffen et al., 2007).

A final issue is whether the exercises used were appropriate. In both of the team handball injury prevention programs (Myklebust et al., 2003; Olsen et al., 2005), focus was placed on technique training in high-risk situations identified from video analysis of ACL injuries (Olsen et al., 2004). Although it may be reasonable to assume that female football players would also benefit from not allowing the knee to pivot medially during cut and plant movements and after landings, there is no direct evidence identifying the injury mechanisms in female youth football. It may be that, unlike team handball, knee and ankle injuries in football to a greater extent result from direct contact with the lower extremity, with less potential for intervention through balance or fitness training. More dynamic exercises resembling football play and injury-risk situations, like running with rapid changes of direction, dribbling, landing after heading and perturbations (Giza et al., 2003; Andersen et al., 2004; Árnason et al., 2004), may be some ways to adjust to the program.

Methodological issues

Lack of randomization (Caraffa et al., 1996; Heidt et al., 2000; Junge et al., 2002; Mandelbaum et al., 2005), low study power (Caraffa et al., 1996; Heidt et al., 2000; Söderman et al., 2000; Junge et al., 2002) and a high drop-out rate (Söderman et al., 2000; Junge et al., 2002) are some of the limitations in former investigations on injury prevention in football. The main strength of the present investigation is its design as a randomized-controlled trial with a large sample size. The intraclass correlation coefficient, which was calculated to 0.06, gave us an inflation factor of 1.8. However, even if the sample size estimate was accurate, study power was still limited. The final sample of 2020 players provided a statistical power of 0.76 to detect a group difference of 40% in the number of players with a knee or ankle injury. However, this means that we cannot rule out that there may have been beneficial effects on specific injury types. For example, on comparing the subgroup of teams who completed more than 20 training sessions with the control group, in absolute numbers the rate of severe injuries was 42% lower, the rate of moderate injuries 25% lower and the rate of reinjuries was 28% lower within the intervention teams than the control teams (see Table 4). However, the number of injuries in each of these groups is limited and the effect of the program on specific injury types therefore cannot be assessed reliably.

The same registration method as in the present study was successfully used by Olsen et al. (2005). The reliability and validity of the exposure and injury registration have been discussed in detail previously (Olsen et al., 2006), and found to be adequate. The proportion of injured players (20%) during one competitive season was considerably lower than reported from a similar cohort of young female Swedish players (41%) (Söderman et al., 2001), but their incidences of acute match (9.1 injuries per 1000 h) and training injuries (1.5 per 1000 h) were similar to the present injury rates. A higher playing exposure among the Swedish players explains the higher proportion of injured players. Therefore, the present injury rates are comparable with previous studies in female youth football (Söderman et al., 2001; Emery et al., 2005). Moreover, if injuries were missed, there is no reason to expect a difference between the intervention and control groups. Nevertheless, one limitation of the present registration method is that, in contrast to Söderman et al. (2000) and Myklebust et al. (2003), individual exposure data were not recorded, which means that it was not possible to perform a sub-group analysis on the individual level.

Perspectives

The benefits of prevention training on injury risk among young female football players have been documented in two trials (Heidt et al., 2000; Mandelbaum et al., 2005). Low compliance among the players, as seen in the current study, is a limitation, and a total of 15 prevention training sessions completed over a 3-month period are insufficient to reduce injury rates. Similar to what has been seen in young Swedish female players (Söderman et al., 2001), the injury pattern among young female players seems to differ from male professional (Hägglund et al., 2005; Waldén et al., 2005) and youth football (Junge et al., 2004b), where groin and hamstring injuries represent as much of a problem as knee and ankle sprains. Among female football players, knee and ankle injuries predominate (Heidt et al., 2000; Östenberg & Roos, 2000; Söderman et al., 2000, 2001; Faude et al., 2005; Giza et al., 2005; Mandelbaum et al., 2005). It therefore seems reasonable to suggest that injury prevention programs for this target group should emphasize lower extremity neuromuscular control, strength and balance training (Hewett et al., 2006). Based on previous research (Hewett et al., 1999; Heidt et al., 2000; Myklebust et al., 2003; Olsen et al., 2005), it appears that such prevention programs should include at least 15 training sessions during the first 6–8 weeks of training. However, further research is needed on how to develop and implement such programs to be as effective as possible in this age and gender group.

Conclusion

In conclusion, we observed no effect of the injury prevention program on the injury rate, most likely because the compliance with the program was low.

Key words: injuries, prevention, neuromuscular training, strength, compliance, soccer.

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Paper III

SUPPLEMENT

Risk of injury on artificial turf and natural grass in young female football players

Kathrin Steffen, Thor Einar Andersen, Roald Bahr

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See end of article for authors' affiliations

Correspondence to: Kathrin Steffen, Oslo Sports Trauma Research Center, Department of Sports Medicine, Norwegian School of Sport Sciences, PO Box 4014 Ullevål Stadion, 0806 Oslo, Norway; kathrin.steffen@nih.no

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Background: Artificial turf is becoming increasingly popular, although the risk of injury on newer generations of turf is unknown.
Aim: To investigate the risk of injury on artificial turf compared with natural grass among young female football players.
Study design: Prospective cohort study.
Methods: 2020 players from 109 teams (mean (SD) 15.4 (0.8) years) participated in the study during the 2005 football season. Time-loss injuries and exposure data on different types of turf were recorded over an eight-month period.
Results: 421 (21%) players sustained 526 injuries, leading to an injury incidence of 3.7/1000 playing hours (95% CI 3.4 to 4.0). The incidence of acute injuries on artificial turf and grass did not differ significantly with respect to match injuries (rate ratio (RR) 1.0, 95% CI 0.8 to 1.3; p = 0.72) or training injuries (RR 1.0, 95% CI 0.6 to 1.5, p = 0.93). In matches, the incidence of serious injuries was significantly higher on artificial turf (RR 2.0, 95% CI 1.3 to 3.2; p = 0.03). Ankle sprain was the most common type of injury (34% of all acute injuries), and there was a trend towards more ankle sprains on artificial turf than on grass (RR 1.5, 95% CI 1.0 to 2.2; p = 0.06).
Conclusion: In the present study among young female football players, the overall risk of acute injuries was similar between artificial turf and natural grass.

In most countries, football is traditionally played on natural grass. However, for climatic and economic reasons, artificial turf has become a popular alternative playing surface—for example, in Scandinavia.[1–3] Many pitches are being built, although the risk of injury on artificial turfs is poorly documented. Concerns have been raised that playing on different surfaces and switching between turfs may lead to an increased risk of injury in elite as well as in amateur football.[4–6] The stiffness of the field surface, its quality and the friction between the surface and shoe are key factors involved in surface-related injuries.[2 7] Field stiffness affects impact forces and can result in overload of tissues such as bone, cartilage, muscle, tendon and ligament. Friction is necessary for rapid starting, stopping, cutting and pivoting in football,[7 8] but injuries can result if friction is too high.[9]

The first generation of synthetic turfs appeared in the mid 1970s.[10] They had short, thin fibres and were characterised by high stiffness and friction, leading to considerable differences in ball behaviour compared with natural grass. Since then, turfs have been developed with a sand filling, leading to reduced friction and lower ball bounce. In the late 1980s, the second generation of artificial turfs was introduced with longer, thicker fibres, better quality sand fillings and a rubber base under the turf itself to reduce stiffness.[11] These were the first turfs designed specifically for football, however, their characteristics still differed appreciably from that of natural grass. The risk of injury was higher on these turfs.[4 12] The third generation of synthetic turfs was introduced in Norway in 2000, consisting of even longer fibres (50–60 mm) and filled with siliceous sand and rubber granules to mimic more closely the playing characteristics of natural grass pitches.[11]

Some studies on American and Canadian football suggest that the incidence of major injuries and ligament sprains is lower when playing on natural grass than on later generation artificial turfs,[13 14] whereas others have shown conflicting findings.[15] However, American and Canadian football codes differ considerably from European football in their playing characteristics and injury mechanisms so it is not known whether these results can be extrapolated to European football. A recent study from Europe, which included the first data on third generation artificial turfs, indicated that the risk of injury among professional male players is similar to that when playing on natural grass.[3] The purpose of this one-season prospective cohort study was to examine the risk of injury on artificial turf compared with natural grass among young female football players.

METHODS

Study population

This study is based on data from a large randomised trial comparing the risk of injury between an intervention group receiving a training programme to prevent injuries and a control group training as usual. The design, the intervention programme and the results of the study have been described in detail elsewhere.[16] All teams (n = 157) in the southeast regions of Norway registered to participate in the U-17 league system in the 2005 season were invited to take part in the study and 113 teams accepted. The competitive season lasted from the end of April until mid-October. There was a seven-week summer break with no regular league matches but some invitational tournaments. The teams were also followed for two months of the preseason period (March–April). Throughout the competitive season, the teams played 14–24 league matches and trained one to three times a week.

Before the start of the preseason, the players were given written and verbal information about the study, and it was emphasised that participation was voluntary. The regional committee for research ethics approved the study, and written consent was obtained. A player was enrolled if she was registered by the team as participating in the U-17 league system, which meant that she had to be 16 years or younger. However, a team competing in the U-17 league can apply for exemption and employ older players if it does not have enough eligible players. All the players were screened using a questionnaire for previous injuries and current joint and muscle function at the start of the study. Players had to be uninjured to be included in the study.

Injury and exposure registration

To monitor injuries and playing exposure, 18 physical therapists were recruited as injury recorders and assigned to the teams (typically five to seven teams each) to record injuries during the period from 1 March to 31 October 2005. All the coaches were asked to keep a log of the data requested. They were contacted by telephone and/or email at least once a month to record new injuries, as well as all training and match activities, including exposure to different types of turf: natural grass, artificial turf, gravel and indoor floor. Injured players were interviewed by the injury recorders to assess aspects of the injury with the use of a standardised injury questionnaire. A web-based system was used to record all the information.

In accordance with the consensus statement on injury definitions,[17] an injury was registered if the player could not fully take part in match or training sessions the day following the injury ("time loss" injury). Acute injuries were defined as injuries with a sudden onset, associated with known trauma. Overuse injuries were those with a gradual onset and no known trauma. Because overuse injuries have a gradual onset, they cannot be attributed to a particular turf type, and therefore, their incidence cannot be compared between turfs. Recurrent injuries were defined as an injury of the same type and the same site as the index injury, and which occurred after a player had returned to full participation following the index injury.

In addition to turf type, the location of the injury, the type of injury and the injury circumstances (contact vs non-contact) were recorded. 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 organised football play: minor (1–7 days), moderate (8–21 days) and major (>21 days).[18] In almost all cases of moderate and major injuries, the player was seen in a medical centre and the injury was diagnosed based on clinical examination, imaging studies or surgery. In cases of minor injuries, a player was usually examined by a physical therapist, the coach or not at all. None of the injured players was examined or treated by any of the authors or injury recorders participating in the study.

Data on match and training exposure were collected on a team basis. The injury incidence was calculated as the number of injuries/1000 player hours, in total, during match play and during training. To calculate match exposure, match playing time (in min) was multiplied by 11 and for training exposure, training time (in min) was multiplied by the average monthly player attendance. A regular league match was played for 2×40 min, whereas a training session usually lasted 90 min.

Statistics

Results are presented as means and 95% confidence intervals (CI), unless otherwise noted. All tests were two tailed and p values <0.05 were considered significant. We used a z test and 95% CI based on the Poisson model to compare the rate ratio between artificial turf and natural grass. Rate ratios are presented with natural grass as the reference group. Since we did not find any differences in the rates of injury in the intervention and control groups,[16] the analyses did not factor in group assignment.

RESULTS

Inclusion of players

The final study sample consisted of 109 teams with 2020 players. Before the start of the season, four teams withdrew from participation in the league system, and their players (n = 72) were excluded from the study. During the season, 48 players (2.3%) stopped playing football for unknown reasons.

Overall rate of injury

During the eight-month season, including the two-month preseason, the total exposure to football on all four turf types was 142 721 h; 41 311 h during matches and 101 410 h during training (table 1). Of the 2020 players, 421 (20.8%) sustained at least one injury, with 68 (3.4%), 17 (0.8%) and 1 (0.05%) incurring two, three and four injuries, respectively, leading to a total of 526 injuries. Of these, 456 were acute injuries (343 during matches and 113 during training) (table 1) and 70 were overuse injuries. The mean (SD) age of the injured players, as well as of the total study population, was 15.4 (0.8) years.

The overall (acute and overuse) incidence of injury on all turf types was 3.7/1000 playing hours (95% CI 3.4 to 4.0). The incidence of acute injuries was 3.2 injuries/1000 h (95% CI 2.9 to 3.5)—8.3 injuries/1000 h (95% CI 7.4 to 9.2) during match play and 1.1 injuries/1000 h (95% CI 0.9 to 1.3) during training. In other words, the incidence of acute injuries was 7.5 times (95% CI 6.0 to 9.2) higher in matches than during training. For overuse injuries, the overall incidence was 0.5 injuries/1000 playing hours (95% CI 0.4 to 0.6). The most common overuse injuries were anterior lower leg pain (36% of all overuse injuries) and knee pain (21%). Of the acute injuries, 42% (191) were non-contact while 58% (265) were sustained by player-to-player contact. Ankle sprain was the commonest type of acute injury with a total of 154 injuries (34% of all acute injuries), of which 52 were recurrent ankle sprains. Of all ankle sprain injuries, 64% (n = 99) were contact injuries, with a higher proportion occurring during matches (82%, n = 81) than in training (18%, n = 18) (p<0.001).

Injuries on grass versus artificial turf

The relative exposure during matches was higher on grass than on artificial turf and other playing surfaces (table 1). Thus, because injuries were more common in matches and matches were more often played on grass, the proportion of match exposure to training exposure satisfies the conditions for being

Table 1 Exposure, number of acute injuries and incidence of acute injuries on different turfs

	Exposure, playing hours (%)			Number of injuries			Injury incidence, n/1000 playing hours (95% CI)	
	Match	Training	Total	Match	Training	Total	Match	Training
Grass	27 627 (67)	45 417 (45)	73 044 (51)	230	56	286	8.3 (7.2 to 9.4)	1.2 (0.9 to 1.6)
Artificial turf	9402 (23)	30 577 (30)	39 979 (28)	82	37	119	8.7 (6.8 to 10.6)	1.2 (0.8 to 1.6)
Gravel	3905 (9)	21 251 (21)	25 156 (18)	26	16	42	6.7 (4.1 to 9.2)	0.8 (0.4 to 1.1)
Indoor	377 (1)	4165 (4)	4542 (3)	5	4	9	13.3 (1.6 to 24.9)	1.0 (0 to 1.9)
Total	41 311	101 410	142 721	343	113	456	8.3 (7.4 to 9.2)	1.1 (0.9 to 1.3)

Table 2 Characteristics of acute injuries incurred during matches

	Grass		Artificial turf		Artificial turf vs grass
	Injuries	Incidence n/1000 h of exposure (95% CI)	Injuries	Incidence n/1000 h of exposure (95% CI)	Rate ratio (95% CI)†
Total	230	8.3 (7.2 to 9.4)	82	8.7 (6.8 to 10.6)	1.0 (0.8 to 1.3)
Injury type					
Contusion	74	2.7 (2.1 to 3.3)	22	2.3 (1.4 to 3.3)	0.9 (0.5 to 1.4)
Sprain	91	3.3 (2.6 to 4.0)	43	4.6 (3.2 to 5.9)	1.4 (1.0 to 2.0)
Strain	41	1.5 (1.0 to 1.9)	6	0.6 (0.1 to 1.1)	0.4 (0.2 to 1.1)
Other	24	0.9 (0.5 to 1.2)	11	1.2 (0.5 to 1.9)	1.3 (0.7 to 2.7)
Re-injuries	38	1.4 (0.9 to 1.8)	20	2.1 (1.2 to 3.1)	1.5 (0.9 to 2.7)
Ankle sprains	22	0.8 (0.5 to 1.1)	14	1.5 (0.7 to 2.3)	1.9 (1.0 to 3.7)
Body location					
Upper body	43	1.6 (1.1 to 2.0)	12	1.3 (0.6 to 2.0)	0.8 (0.4 to 1.6)
Lower body	187	6.8 (5.8 to 7.7)	70	7.4 (5.7 to 9.2)	1.1 (0.8 to 1.4)
Groin	8	0.3 (0.1 to 0.5)	1	0.1 (−0.1 to 0.3)	0.4 (0 to 2.9)
Thigh	32	1.2 (0.8 to 1.6)	7	0.7 (0.2 to 1.3)	0.6 (0.3 to 1.5)
Knee	31	1.1 (0.7 to 1.5)	18	1.9 (1.0 to 2.8)	1.7 (1.0 to 3.1)
Ankle	82	3.0 (2.3 to 3.6)	38	4.0 (2.8 to 5.3)	1.4 (0.9 to 2.0)
Other	34	1.2 (0.8 to 1.6)	6	0.6 (0.1 to 1.1)	0.5 (0.2 to 1.2)
Time loss (days)					
1–7	111	4.0 (3.3 to 4.8)	25	2.7 (1.6 to 3.7)	0.7 (0.4 to 1.0)
8–21	73	2.6 (2.0 to 3.2)	26	2.8 (1.7 to 3.8)	1.0 (0.7 to 1.6)
>21	46	1.7 (1.2 to 2.1)	31	3.3 (2.1 to 4.5)	2.0 (1.3 to 3.1)*

*p<0.05.
†Rate ratios between injuries on grass and artificial turf, with grass as the reference group. Subcategories for injuries on gravel and indoor floors are not shown separately because of small numbers.

a confounder. Rate ratios comparing the total injury incidence between these two turfs would have been confounded by the match to training factor. Therefore the injury incidences, rate ratios between turf types and injury characteristics are presented separately for match and training injuries. We did not find any significant differences, neither for match nor for training injuries, when the incidence of acute injuries was compared between artificial turf and grass (table 1). The rate ratio on artificial turf relative to grass was 1.0 (95% CI 0.8 to 1.3; $p = 0.72$) for match injuries (table 2) and 1.0 (95% CI 0.6 to 1.5; $p = 0.93$) for training injuries.

Injury rates were similar on artificial turf and grass for most subcategories of injury types and locations (table 2). In matches, twice as many severe injuries occurred on artificial turf as on grass ($p = 0.03$), whereas the rate for minor injuries tended to be significantly lower when playing on artificial turf than on grass ($p = 0.06$). A trend was also seen towards more ankle ligament injuries on artificial turf than on grass (rate ratio 1.5, 95% CI 1.0 to 2.2; $p = 0.06$), as well as for more ligament injuries in general ($p = 0.07$) and more knee injuries ($p = 0.07$).

The incidence of acute match injuries on artificial turf and grass did not differ significantly when compared for different injury mechanisms (contact: $p = 0.91$; and non-contact injuries: $p = 0.64$). However, when examining the activities leading to injury, significantly more injuries from heading duels occurred on artificial turf than on grass ($p = 0.04$; table 3).

There were 11 injuries of the anterior cruciate ligament, which corresponds to an incidence of 0.08/1000 playing hours; three occurred on grass, four on artificial turf, two on gravel and two on indoor floor (p = not significant). Ten of these injuries occurred in matches: four due to player-to-player contact and six in a non-contact situation. The training injuries resulted from player-to-player contact.

With regard to injuries on, there were not enough injuries and exposures to compare gravel and indoor floor between turf types.

DISCUSSION

The principal finding of our eight-month prospective cohort study was that there was no overall difference in the risk of acute injuries between artificial turf and natural grass in a

Table 3 Mechanisms of acute injuries incurred during matches

	Grass		Artificial turf		Artificial turf vs grass
	Injuries	Incidence n/1000 h of exposure (95% CI)	Injuries	Incidence n/1000 h of exposure (95% CI)	Rate ratio (95% CI)†
Contact	153	5.5 (4.7 to 6.4)	53	5.6 (4.1 to 7.2)	1.0 (0.7 to 1.4)
Non-contact	77	2.8 (2.2 to 3.4)	29	3.1 (2.0 to 4.2)	1.1 (0.7 to 1.7)
Activity					
Tackling	124	4.5 (3.7 to 5.3)	40	4.3 (2.9 to 5.6)	0.9 (0.7 to 1.4)
Heading duel	5	0.2 (0 to 0.3)	6	0.6 (0.1 to 1.1)	3.5 (1.1 to 11.6)*
Running	51	1.8 (1.3 to 2.4)	14	1.5 (0.7 to 2.3)	0.8 (0.4 to 1.5)
Collision	17	0.6 (0.3 to 0.9)	7	0.7 (0.2 to 1.3)	1.2 (0.5 to 2.9)
Other	33	1.2 (0.8 to 1.6)	15	1.6 (0.8 to 2.4)	1.3 (0.7 to 2.5)
Total	230	8.3 (7.2 to 9.4)	82	8.7 (6.8 to 10.6)	1.0 (0.8 to 1.3)

*p<0.05.
†Rate ratios between injuries on grass and artificial turf, with grass as the reference group. Subcategories for injuries on gravel and indoor floors are not shown separately because of small numbers.

What is already known on this topic

- Previous research on risk of injury related to playing on artificial turf mainly relates to older turf generations and/or other football codes, and the results are conflicting.
- Only one study has compared the injury risk on third generation artificial turf with natural grass. It showed that the rate of injury is similar on both turf types among male professional football players.
- It is not known if the injury risk among young female football players differs between artificial turf and natural grass.

What this study adds

- This study did not find any deleterious effect of artificial turf on the overall risk for acute injuries in young female football players when compared with natural grass.

group of young female football players. This is the first study to assess the relationship between the types of turf and risk of injury in youth football. The main limitation is that, although this is the largest study to date on the relationship between turf types and injury risk in European football, the statistical power was still limited with respect to injury subgroups. Therefore, it is not possible to rule out differences in risk for specific injury types or for injuries on gravel and indoor floor or training injuries.

A few small, older studies examined the extrinsic risk factors for football injuries, such as weather conditions[19 20] and playing surfaces,[4 12] but on first generation artificial turf.[4 12] The findings have been inconsistent. High friction and stiff field quality were assumed to explain the higher rates of injury observed on artificial turf in these older studies on elite male football players,[4 12] but the second and third generation artificial turfs examined in the present study differ considerably from the first generation turfs and may explain the divergent results. The present results corroborate with those of a recent study on professional men's football, which showed similar incidences of injury on third generation artificial turfs and natural grass.[3] The overall injury incidences reported in the present study are similar to those reported in two previous epidemiological studies on female youth football.[21 22]

It has been speculated that frequent changes in playing surfaces and the players' lack of adaptation to them increases the risk for overuse injuries, such as low back and lower limb pain.[7] This hypothesis, reinforced by several researchers,[4 6 23] is difficult to test in epidemiological studies. According to the definition, overuse injuries have a gradual onset and can neither be attributed to a specific event nor a particular turf type. Even if a player reports that they first experienced symptoms during a particular match or training session, the injury may have been incurred in one or more previous sessions on a different turf type.

When interpreting our results it is to be noted that there are several other extrinsic factors which we did not control for in the present study. Potential confounding factors include the generation of the artificial turfs used in this project and the maintenance status for both synthetic and grass turfs. Weather conditions have also been suggested to affect injury risk.[13–15] A US football study reported higher rates of lower extremity injury on artificial turf than on natural grass, under both wet and dry field conditions.[13] Since neither meteorological data nor field conditions were registered in this study, we cannot assess the contribution of these factors to injury risk. Also, we do not know how internal risk factors such as previous injuries, age, joint instability, physical fitness or skill levels may have contributed to injury rates.[21 24–28]

In northern climates it may not be possible to play on natural grass for more than a few months a year, and artificial turf and gravel are the only surface options, particularly in youth football. In addition, artificial turf tolerates frequent, even continuous, use.[11] Increased pitch availability and higher utilisation of artificial turf pitches may also lead to better maintenance routines and generally more consistent pitch conditions than before. On newer generation artificial turfs, better shock absorption, supported by an underground heating system during cold periods, may attenuate impact forces to the muscle and tendon structures. However, note that we did not observe any clear trend towards fewer injuries on artificial turf than on natural grass in the present investigation. Given the practical advantages of artificial turf, it is promising that we did not find any deleterious effect of artificial turf on the overall risk for acute injuries among young female players. The number of injuries was insufficient to compare the risk of injury between turf types for each specific injury type, such as for knee sprains or injuries of the anterior cruciate ligament. Nevertheless, we did note some differences or trends with regard to the risk of injury for specific subgroups (mild and severe injuries, ankle ligament injuries, ligament injuries in general and knee injuries). Shoe-surface friction, which is assumed to be higher on synthetic than on natural material, has been associated with injuries in team handball[9] and in football.[7 14] The observed trends for ankle and knee injuries and ligament injuries in general indicate that differences in friction may have a role. Ligament sprains to ankles and knees, the most severe injuries in this study, often occur in situations when the player is out of balance while the loaded leg is fixed to the ground.[7 29 30] However, these hypotheses need to be examined in larger studies. Moreover, it is not known whether the observed trends are specific for females. A study on team handball showed that risk of ACL injury was higher on artificial floors than on wooden floors among female players, but this difference was not seen in male players.[9]

CONCLUSION

Our eight-month register of injuries among young female football players showed that the overall risk of injury is the same when playing and training on artificial turf as on natural grass.

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Authors' affiliations

Kathrin Steffen, Thor Einar Andersen, Roald Bahr, Oslo Sports Trauma Research Center, Department of Sports Medicine, Norwegian School of Sport Sciences, Oslo, Norway

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Paper IV

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Self-Reported Injury History and Lower Limb Function as Risk Factors for Injuries in Female Youth Soccer

Kathrin Steffen,* MSc, Grethe Myklebust, PT, PhD, Thor Einar Andersen, MD, PhD, Ingar Holme, PhD, and Roald Bahr, MD, PhD
From the Oslo Sports Trauma Research Center, Department of Sports Medicine, Norwegian School of Sport Sciences, Oslo, Norway

Background: Identifying and understanding injury risk factors are necessary to develop and target measures to prevent injuries. Because youth teams rarely have health care professionals working directly with the team, identifying players at increased risk through elaborate clinical tests is not feasible. Questionnaires may be a possible alternative as screening instruments.

Purpose: To examine whether injury history and lower limb function assessed by a self-administered questionnaire represent risk factors for injury.

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

Methods: At baseline, female soccer players (aged 14-16 years) were asked to complete a detailed questionnaire covering sports participation; history of previous injuries to the ankle, knee, hamstring, or groin; as well as present function of these 4 specific regions. A total of 1430 (71% of the entire cohort) were followed up to record injuries during the subsequent 8 months.

Results: A history of a previous injury to the ankle (rate ratio, 1.2 [1.1-1.3]; $P < .001$), knee (rate ratio, 1.4 [1.2-1.6]; $P < .001$), or groin (rate ratio, 1.6 [1.2-2.1]; $P = .004$) increased the risk of new injuries to the same region. Reporting a reduced function (defined as <80% of the maximum score) for the ankle (rate ratio, 1.7 [1.1-2.7]; $P = .021$) or knee (rate ratio, 3.2 [1.8-5.7]; $P < .001$) was also a significant risk factor. However, the sensitivity of previous injuries and lower limb function in predicting new injuries was low.

Conclusion: A history of previous injury and reduced function at baseline were significant risk factors for new injuries to the same region during the following season.

Keywords: youth; soccer; risk factor; lower limb; injury; screening

Female soccer has grown exponentially worldwide and in Scandinavia in particular. Of all organized soccer players in the United States in 2006, 30% were female players.[19] More than 36 000 female players aged between 13 and 19 years were registered in Norway, a country with 4.6 million inhabitants, representing an annual growth of 10% to 13% during the last 5 years.[41] Because sports is one of the leading causes of injuries in adolescents,[15,34] the increasing popularity of youth soccer has also led to a surge in research related to the injury pattern seen in this athlete population. The injury incidence ranges from 9 injuries per 1000 match hours among adolescent female players[15,48,50] to 10 to 23 injuries among adult female players, depending on their skill level.[22,30,44,49] Injuries to the lower limb are dominant, with the ankle, knee, and thigh as the most common injury locations among adolescent[15,48,50] as well as adult elite players.[16,17,22,30]

However, analyses of risk factors for such injuries among adolescents are surprisingly scarce considering the long-term health consequences after major knee and ankle sprains.[2,36,40] Thus, identifying and understanding risk factors are necessary to develop preventive measures.[5,10] Previous injury has been identified as a risk factor for injury for both genders and at different skill levels,[5,15,26] although not in all studies.[18] Emery et al[15] reported a 74% increase in injury risk among young and adolescent female players with a history of at least 1 previous injury. Other risk factors that have been discussed in the literature are age (older players at higher risk),[5,44] longer career duration,[44] joint laxity,[44,49] mechanical or functional instability,[44,49] lower extremity strength,[7,31,49] muscular imbalances,[31] decreased range of motion,[5] and inadequate rehabilitation.[5,26,51,52]

*Address correspondence to Kathrin Steffen, Oslo Sports Trauma Research Center, Department of Sports Medicine, Norwegian School of Sport Sciences, PO Box 4014 Ullevål Stadion, 0806 Oslo, Norway (e-mail: kathrin.steffen@nih.no).

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Youth teams are rarely attended by trained health professionals, and identifying players at increased risk for injury through clinical testing is therefore not practical. However, if questionnaires could be developed as screening instruments for injuries, they would be time efficient and easy to manage. In soccer, questionnaires have been used at various skill levels to obtain information about the sports and medical history of players, including history of previous injuries.[15,17,48,56] However, to our knowledge, no study has so far addressed joint- or muscle-specific function by questionnaire. The aim of this prospective 1-season cohort study on young female soccer players was therefore to examine whether injury history and lower limb function assessed by a self-administered questionnaire represent risk factors for new injury.

MATERIALS AND METHODS

Study Population

This study is based on data from a randomized trial on female adolescent soccer players examining the effect of a specific training program designed to prevent injuries. The design, the intervention program, and the results of the study have been described in detail in a separate report.[50] Because no differences were seen in injury rates between the intervention and control groups,[50] the analyses did not factor in group assignment, meaning that the intervention was not a covariate for new injuries. Hence, group assignment would not have been a confounder for the relationship and prediction of new injuries.

All teams (N = 157) in the southeast region of Norway that had registered to participate in the under-17 (U17) league system in the 2005 season were invited to take part in the study. Of these, a total of 113 teams volunteered to be included. The competitive season lasted from the end of April until mid-October, interrupted by a 7-week summer break without regular league matches but with some invitational tournaments. The teams were also followed for 2 months of the preseason period (March-April). Throughout the competitive season, the teams played 14 to 24 league matches and trained 1 to 3 times a week.

Before the start of the preseason, the players received written and oral information about the study, and it was emphasized that participation was voluntary. The study was approved by the regional committee for research ethics, and written consent was obtained. A player was entered into the study if she was registered by the team as participating in the U17 league system, which means that she had to be 16 years old or younger. However, teams competing in the U17 league could apply for exemption to use older players if they did not have enough eligible players. Players who were injured at the start of the study were included from the time they returned to play, but this preexisting injury was not included in the data analysis.

Risk Factor Questionnaire

At baseline, each player was asked to complete a detailed questionnaire covering sports participation; history of previous injuries to the ankle, knee, hamstring, or groin; as well as present symptoms and function of these 4 specific regions. Ankle function and knee function were classified using the Foot and Ankle Outcome Score (FAOS)[46] and the Knee and Osteoarthritis Outcome Score (KOOS)[47] forms, respectively, and similar forms were constructed to classify hamstring and groin function by adapting questions from the FAOS and KOOS forms to these muscle groups.

The FAOS and KOOS are self-explanatory 42-item questionnaires developed to assess patient opinion about ankle- and knee-associated problems, respectively, after ligament reconstruction or other surgical treatment.[11,47] Patient-relevant outcomes are measured in 5 separate subscores: pain, other symptoms, activities of daily living, sport and recreation function, and ankle-/knee-related quality of life (QOL). Both questionnaires meet set criteria of validity and reliability.[46,47] The questionnaires developed to assess hamstring (hamstring outcome score [HaOS]) and groin function (groin outcome score [GrOS]) included 19 and 29 items, respectively. These questions formed the basis for the following 5 subscale scores: symptoms, stiffness, pain, sport and recreational function, and hamstring-/groin-related QOL. The reliability and validity of these questionnaires have not been assessed.

A 5-point Likert scale was used to answer each question, and all items were scored from 0 (no problem) to 4 (extreme problems). Each of the 5 subscale scores was calculated as a sum of the items included, composing a raw score. Raw scores were transformed to a total score, ranging from 0 to 100, with 100 representing optimal function. The criteria for classifying a leg as having an increased risk of injury were as follows: a history of an injury to the ankle, knee, hamstring, or groin or a reduced function with a mean score of less than 80% for either of the 4 body parts mentioned.

The forms used were designed to be read optically, and data were transformed into an SPSS database (SPSS for Windows 15.0, SPSS Inc, Chicago, Ill). If a mark was placed outside a Likert box, the closest box was used. If 2 boxes were marked or a mark was placed between 2 boxes, that box which indicated the more severe problem was chosen. If no mark at all was placed, a missing value for that particular item was registered in the database.

The questionnaire was introduced to the players at a team meeting by staff who were carefully instructed in how the questionnaire should be completed. They were also present to answer questions while the players completed the questionnaire. It took the players about 45 minutes to complete the full questionnaire. Completed questionnaires were missing for players who did not attend the scheduled team meetings and for teams that for unknown reasons were unable to arrange team meetings.

Injury Registration

To monitor all injuries throughout the 8-month study period, 18 physical therapists were recruited and assigned to the teams (typically 5-7 teams each) to record injuries from March 1 through October 31. All coaches were asked to keep a continuous log of all data requested. The coach of each team was contacted by telephone and/or e-mails at least once a month to record new injuries, as well as all playing activities in training and matches. Injured players were interviewed by the injury recorders to assess aspects of the injury based on a standardized injury questionnaire. All information was registered using a Web-based recording system.

An injury was registered if it caused the player to be unable to fully take part in match or training sessions the day after the injury ("time loss" injury).[20] 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. A previous injury was defined as an injury of the same type and the same site as an index injury and that occurred after a player had returned to full participation from the index injury. The location and type of injury were recorded. In almost all cases of moderate and major injuries, the players were seen in a medical center to diagnose the injury by clinical examination, imaging studies, or surgery. In cases of minor injuries, the players were generally examined by a local physical therapist, the coach, or not at all. However, the injury information was obtained from the interviews with injured players. None of the injured players were examined or treated by any of the authors or injury recorders involved in the study.

Statistics

As stated above, this cohort study represents a secondary analysis of data from a randomized controlled trial.[50]

Descriptive data, such as anthropometrics, player history, and sum scores for the 4 function scores, are presented as mean values with SDs. Groups of injured and uninjured players were compared using the Student *t* test, and group differences are presented as mean values with 95% confidence intervals (CIs). *P* values below .05 were considered significant.

As in other recent studies on lower limb risk factors,[5,8,26] each limb was used as the unit of analysis. An odds ratio (OR) with 95% CI was calculated for a group of players with previous injuries versus new injuries. The predictive values of anthropometric and player history data, previous injuries, and the 4 different function scores in relation to new injuries were analyzed using Poisson regression models based on generalized estimating equations. The number of new injuries was used as the dependent variable, whereas the number of previous injuries as well as function scores were used as independent variables. All regression models were adjusted for the effects of cluster (person and team, using geographic region as surrogate). Rate ratios (RRs) with 95% CIs associated with a 1 SD decrease in the exposure variable (function score; total and subscores) were calculated to compare the risk for new injuries between players. Similarly, we calculated RR with 95% CI for a 1-unit increase in the number of years of play and previous injuries, as well as a 1-unit change for the groups of players with low function scores. Limb as the unit of analysis was also used for the calculation of the sensitivity and specificity of previous injuries and lower limb function in predicting new injuries.

RESULTS

Baseline Data

A total of 1430 players (71% of the entire cohort)[50] completed the questionnaire on history of previous injuries and present lower limb function. The mean age of these players was 15.4 years (SD, 0.8). Their mean weight was 56 kg (SD, 7), height was 166 cm (SD, 6), and body mass index was 20 kg/cm^2 (SD, 2). Anthropometric data, player history, as well as joint- and muscle-specific function scores at baseline are described separately for previously injured and uninjured players (Table 1). There were highly significant between-group differences for all of the 4 function scores, as well as for the 5 subscores within each function score in disfavor of previously injured players, except for hamstring-related QOL (*P* = .21) (Table 2).

TABLE 1
Baseline Data (Mean ± SD) for Previously Injured and Uninjured Players Regarding Player Characteristics and Training History

	Previously Injured (n = 1003)	Previously Not Injured (n = 422)
Age, y	15.4 ± 0.8	15.3 ± 0.8
Weight, kg	55.9 ± 7.2	55.1 ± 7.5
Height, cm	166.3 ± 5.6	165.9 ± 6.0
Body mass index, kg/cm^2	20.2 ± 2.2	20.0 ± 2.3
No. of years in organized soccer	5.5 ± 2.2	5.1 ± 2.1
Hours of training per week	7.6 ± 3.2	7.0 ± 3.0
Hours of soccer training per week	4.4 ± 2.5	4.1 ± 2.0

Overall Injury Characteristics

A total of 296 of the 1430 players (20.7%) sustained at least 1 injury. Of these players, 49 (3.4%), 16 (1.1%), and 1 (0.07%) incurred 2, 3, and 4 injuries, respectively, leading to a total of 380 injuries. There were 330 acute injuries and 50 overuse injuries. The most common types of overuse injury were anterior lower leg pain (35% of all overuse injuries) and knee pain (21%), whereas an ankle sprain was the most common acute injury type (111 injuries, 34%). Of the 330 acute injuries, 70 (21%) were reinjuries. The type and location of acute injuries are described in Table 3.

Risk Factors for New Injuries

As many as 1003 players (70.1%) reported to have had at least 1 previous injury to 1 of the 4 body regions covered by the questionnaire: ankle, knee, hamstring, or groin. Of these, 179 players (17.8%) sustained at least 1 new injury during the 2005 season to the same region, compared with 38 players (9.0%) among players with no injury history. Thus, the risk of injury was almost twice as high for players with an injury history to the same region on the same site during the study period than for players without previous injuries (OR, 1.9; 95% CI, 1.4-2.5; *P* < .001). The risk of sustaining a new injury increased with the number of previous injuries (RR, 1.08 [1.04-1.12] for each additional previous injury reported; *P* < .001). None of the anthropometric variables (age, height, weight, body mass index) or weekly sports participation were significant risk factors for new injuries. However, years of organized soccer play

TABLE 2
Baseline Ankle, Knee, Hamstring, and Groin Scores for Previously Injured and Uninjured Legs[a]

Subscore	Previously Injured	Previously Not Injured	Δ (95% CI)
Ankle (FAOS)	n = 936	n = 1485	
Pain	92.0 ± 11.3	97.3 ± 6.0	–5.3 (–6.0 to –4.5)
Symptoms	62.8 ± 11.1	68.2 ± 9.7	–5.4 (–6.3 to –4.5)
Activities of daily living	96.3 ± 7.5	98.7 ± 4.2	–2.3 (–2.9 to –1.8)
Sport	89.0 ± 16.2	96.3 ± 8.4	–7.3 (–8.4 to –6.2)
Quality of life	71.3 ± 12.4	76.3 ± 10.0	–5.0 (–5.9 to –4.0)
Total	411.5 ± 46.8	436.7 ± 26.8	–25.2 (–28.5 to –21.9)
Knee (KOOS)	n = 649	n = 1869	
Pain	87.6 ± 15.4	96.8 ± 8.2	–9.2 (–10.1 to –8.2)
Symptoms	58.6 ± 12.9	67.1 ± 10.1	–8.5 (–9.5 to –7.4)
Activities of daily living	93.4 ± 11.0	98.3 ± 5.7	–4.9 (–5.8 to –4.0)
Sport	80.5 ± 22.3	94.8 ± 12.4	–14.2 (–16.1 to –12.4)
Quality of life	65.9 ± 13.0	74.2 ± 10.0	–8.3 (–9.4 to –7.2)
Total	386.1 ± 64.6	431.2 ± 37.1	–45.1 (–50.4 to –39.8)
Hamstring (HaOS)	n = 451	n = 2169	
Pain	88.9 ± 12.0	95.0 ± 7.6	–6.1 (–7.2 to –4.9)
Symptoms	80.4 ± 23.1	93.3 ± 15.0	–7.9 (–9.9 to –5.9)
Stiffness	87.0 ± 13.3	91.6 ± 10.5	–4.6 (–5.9 to –3.3)
Sport	95.1 ± 11.4	98.2 ± 6.5	–3.1 (–4.2 to –2.0)
Quality of life	53.6 ± 16.3	54.8 ± 18.2	–1.2 (–3.0 to 0.7)
Total	408.4 ± 46.3	431.2 ± 37.3	–22.8 (–27.4 to –18.3)
Groin (GrOS)	n = 363	n = 2271	
Pain	92.7 ± 10.7	97.3 ± 4.9	–4.5 (–5.7 to –3.4)
Symptoms	80.4 ± 23.1	93.3 ± 15.0	–11.9 (–14.4 to –9.5)
Stiffness	92.6 ± 10.4	96.7 ± 6.7	–4.1 (–5.7 to –3.4)
Sport	96.1 ± 10.2	99.0 ± 4.0	–2.9 (–4.0 to –1.9)
Quality of life	66.7 ± 13.6	69.1 ± 12.5	–2.4 (–3.9 to –0.9)
Total	428.4 ± 48.1	454.4 ± 29.0	–25.9 (–31.0 to –20.8)

[a]Each leg has been treated as a separate case. Complete function scores were available for 88% of the Foot and Ankle Outcome Score (FAOS), 90% of the Knee and Osteoarthritis Outcome Score (KOOS), and 94% of the hamstring outcome score (HaOS) and groin outcome score (GrOS) forms, respectively. Data are mean ± SD and mean difference (Δ; 95% confidence interval [CI]).

TABLE 3
Number and Proportion of Acute Time Loss Injuries in Relation to Injury Type and Location

								Total	
	Contusion	Sprain	Strain	Dislocation	Fracture	Pain	Other	No.	%
Head/neck	5	1					8	14	4.2
Upper body	9	5	4	1	6		2	27	8.2
Lower body	64	135	73	1	1	1	14	289	87.6
Hip	4							4	1.2
Groin			19					19	5.8
Thigh	3		46					49	14.8
Knee	19	20	2	1			11	53	16.1
Lower leg	12		4				1	17	5.2
Ankle	13	111					1	125	37.9
Foot, including toe	13	4	2		1	1	1	22	6.7
Total (%)	78 (23.6)	141 (42.7)	77 (23.3)	2 (0.6)	7 (2.1)	1 (0.3)	24 (7.3)	330 (100)	

was significantly associated with new injuries (RR, 1.12 [1.04-1.22] for each additional year reported; P = .003). Figure 1 presents the risk of new injuries based on having reported a history of previous injuries to 1 of the 4 regions. Players with an injury history to the ankle, knee, or groin were more likely to sustain a new ankle, knee, or groin injury than were players without previous injuries. Figure 2 presents the risk of new injuries when scoring low (defined as a score below 80%) on 1 of the 4 function scores for the same 4 regions. Having reported reduced function

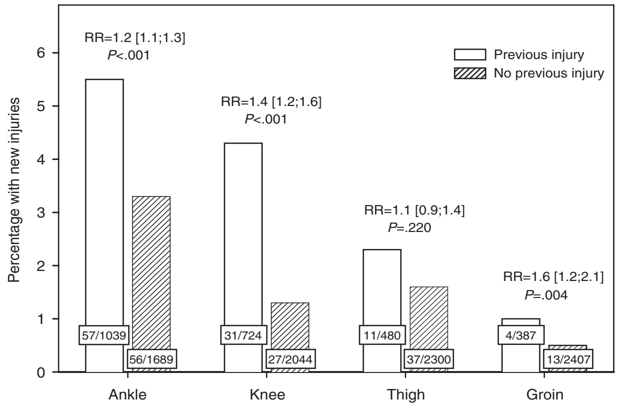

Figure 1. Risk of new injuries for players with previous injuries for each of the 4 specific regions. Each limb has been treated separately in this analysis. RR, relative risk.

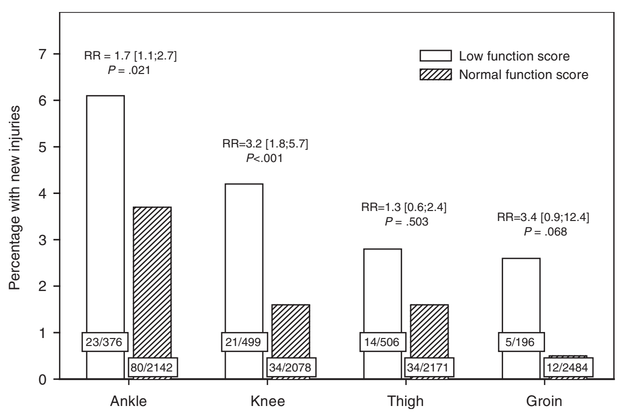

Figure 2. Risk of new injuries for players with low function scores for each of the 4 specific regions. Each limb has been treated separately in this analysis. RR, relative risk.

scores significantly increased the risk of sustaining new ankle or knee injuries.

Poisson Regression

Table 4 shows the subscores of each of the joint- and muscle-specific function scores for players who were injured and not injured during the 2005 season. Table 4 also reports the results from the Poisson regression model, for each subscore and for the total function score. All of the ankle- and knee-specific subscores were significant risk factors for new ankle and knee injuries.

Sensitivity and Specificity to Predict New Injuries

Based on a simplified model with limb as the unit of analysis and each injury treated as a separate case, the sensitivity and specificity of self-reported previous injuries and low function scores to predict new injuries were calculated (Table 5). Reporting a previous ankle or knee injury was more sensitive in predicting new ankle and knee injuries than was reporting a reduced ankle or knee function score. However, this difference in sensitivity was smaller for the prediction of new thigh or groin injuries. The specificity of injury history and joint- and muscle-specific function scores to identify new injuries was higher than for sensitivity, ranging from 62% to 93%, respectively.

DISCUSSION

The principal finding of this prospective cohort study was that young female soccer players with at least 1 previous injury or a reduced lower limb function score had a significantly increased risk of sustaining a new injury of the same kind during the 8-month follow-up period. Thus, we were able to identify athletes prone to be injured at the ankle, knee, thigh, or groin simply by having the players complete a preseason questionnaire on their history of injury and present lower limb function, albeit with low sensitivity.

Almost one fourth of all new acute injuries recorded in the present study were in fact reinjuries, which may come as a surprise in such a young player population. However, the explanation seems quite obvious; as many as 1 in every 5 players sustains an injury every season, and the injury pattern is quite consistent, with hamstring strains and ankle and knee sprains being by far the most common injuries. In addition, previous injury in itself clearly represents a risk factor for injury, possibly through physiologic or anatomical deficits resulting from the previous injury, for example, reduced strength and neuromuscular control or increased joint laxity.[5,15,26,44,49,55] That reinjury rates are high in elite male players is well known,[5,26,54] but our findings are also corroborated by previous studies on female players, reporting the proportion of reinjuries to range between 19%[17] and 41%.[48]

Ankle Injuries

Lateral ligament injuries to the ankle are typical in soccer and mainly result from tackling, running, or landing.[3,6,21] As shown in the present and previous studies on young and adolescent female players,[15,48] ankle sprains represent the dominant injury type and are proportionally more frequent than among youth male[35] or female[16,17,30,44] or male elite players.[5,25,56]

Previous injury has been reported to be a strong risk factor for soccer-related ankle injuries.[5,51,52] However, studies investigating the association between previous and new ankle sprains have produced conflicting results, even at the elite level. In contrast to the present data, showing an 18% increased risk for new ankle injuries, injury risk was increased neither in female[17] nor in male players[26] at the elite level who had reported an ankle sprain history.

The most likely explanation for this apparent discrepancy is that medical care is less available for youth teams than for elite players and that the quality and consistency of the rehabilitation program after injury influence the prognosis of recurrences. In youth sports, knowledge about injury rehabilitation is typically low and access to professional medical care limited. The decision to return to play after an injury is therefore usually made by the coach, the

TABLE 4
Poisson Regression Model Based on Mean Sum Scores for Subscores Within Each of the 4 Function Scores for Legs That Were Injured and Not Injured During the 2005 Season[a]

	Sum Score, Mean ± SD		Poisson Regression Prediction of New Injuries, n	
Subscore	Injured 2005	Not Injured 2005	RR (95% CI)	*P*
Ankle (FAOS)	n = 103	n = 2415		
Pain	92.8 ± 12.6	95.5 ± 8.5	1.22 (1.07-1.40)	.004
Symptoms	65.5 ± 10.9	66.3 ± 10.7	1.24 (1.03-1.50)	.032
Activities of daily living	97.3 ± 7.0	97.8 ± 5.7	1.21 (1.09-1.34)	<.001
Sport	90.0 ± 17.8	93.8 ± 12.1	1.25 (1.08-1.45)	.001
Quality of life	71.4 ± 13.6	74.7 ± 11.2	1.29 (1.07-1.54)	.010
Total	417.0 ± 50.2	428.1 ± 37.0	1.3 (1.1-1.5)	<.001
Knee (KOOS)	n = 55	n = 2522		
Pain	86.2 ± 20.3	94.6 ± 11.0	1.50 (1.29-1.75)	<.001
Symptoms	59.5 ± 9.9	65.0 ± 11.5	1.62 (1.31-1.99)	<.001
Activities of daily living	91.0 ± 14.7	97.2 ± 7.5	1.42 (1.27-1.58)	<.001
Sport	78.3 ± 29.4	91.4 ± 16.4	1.59 (1.39-1.82)	<.001
Quality of life	66.8 ± 14.3	72.2 ± 11.3	1.72 (1.31-2.27)	<.001
Total	381.8 ± 78.9	420.4 ± 48.7	1.6 (1.4-2.0)	.001
Hamstring (HaOS)	n = 48	n = 2629		
Pain	92.0 ± 10.2	94.0 ± 8.8	1.18 (0.99-1.40)	.058
Symptoms	85.9 ± 21.2	90.3 ± 17.2	1.17 (0.92-1.46)	.229
Stiffness	89.1 ± 11.8	90.8 ± 11.2	1.02 (0.78-1.33)	.889
Sport	96.9 ± 6.4	97.7 ± 7.7	1.08 (0.93-1.24)	.316
Quality of life	57.9 ± 20.7	54.5 ± 17.7	1.13 (0.86-1.50)	.414
Total	421.7 ± 44.7	427.3 ± 39.8	1.1 (0.8-1.5)	.530
Groin (GrOS)	n = 17	n = 2663		
Pain	93.5 ± 8.3	96.6 ± 6.2	1.20 (0.99-1.45)	.068
Symptoms	76.5 ± 25.7	90.7 ± 16.9	1.51 (1.01-2.26)	.045
Stiffness	93.1 ± 10.3	96.1 ± 7.4	1.01 (0.64-1.59)	.971
Sport	95.8 ± 8.2	98.6 ± 5.4	1.07 (0.79-1.44)	.657
Quality of life	66.8 ± 19.7	68.8 ± 12.7	1.12 (0.85-1.48)	.398
Total	425.7 ± 58.4	450.9 ± 33.4	1.4 (1.0-1.9)	.056

[a]CI, confidence interval; FAOS, Foot and Ankle Outcome Score; GrOS, groin outcome score; HaOS, hamstring outcome score; KOOS, Knee and Osteoarthritis Outcome Score; RR, rate ratio.

player, and/or the parents. In contrast, the medical staff of professional teams are generally well aware of the principles for optimal treatment and secondary prevention of ankle sprains.[26] Kucera et al[34] also postulated that an increased risk of ankle injuries is consistent with the nature of youth soccer, where kicking, planting, cutting, sprinting, jumping, and landing are performed on partially uneven natural grass pitches, which can be highly stressful for the foot and ankle structures.

An indication that rehabilitation after previous injuries had been inadequate is that the baseline FAOS function score was lower in players with a previous ankle injury compared with uninjured players. It is therefore not surprising that the FAOS function score, in total and all subscores, represents a risk factor for new ankle sprains, although the sensitivity was low. In most cases, pain and swelling are indicators of a poorly rehabilitated injury or signs that the joint is not functionally stable during sports activities.

Knee Injuries

Knee sprains are common in female soccer players, with injury rates several-fold higher than that of male players at the same level.[1,23] Running, turning, and landing after heading in combination with rapid brakes and changes of direction put the knee joint at risk,[28,32,33] although the reasons for the gender gap are not fully elucidated.[23] In the present study, a previous knee injury increased the risk for a new knee injury by 38%, which corresponds to data from other investigations on elite[5,26,55] and adolescent players of both genders.[34]

One fifth of all acute injuries involved the knee joint, and nearly 40% of all acute knee injuries recorded in the present study were ligament sprains. Because there is solid evidence that previous knee sprains increase the risk of early osteoarthritis in soccer players,[36,40,54] the present results suggest that special attention should be given to players with a knee injury history and knee-related symptoms. As was seen for ankle injuries, the baseline KOOS function score was reduced in players with previous knee injuries, again indicating that rehabilitation after injury was insufficient before the start of the season.

Thigh Injuries

Hamstring strains are common in soccer players, presumably resulting from eccentric muscle activity during kicking

TABLE 5
Sensitivity and Specificity for Reported Previous Injury and Low Function Scores (<80%) to the Ankle (FAOS), Knee (KOOS), Hamstring (HaOS), and Groin (GrOS) to Predict New Injuries in the Same Location[a]

	Previous Injury, %		Low Function Score, %	
New Injuries	Sensitivity	Specificity	Sensitivity	Specificity
Ankle	50	62	22	85
Knee	53	74	38	81
Thigh	23	83	29	81
Groin	24	86	29	93

[a]FAOS, Foot and Ankle Outcome Score; GrOS, groin outcome score; HaOS, hamstring outcome score; KOOS, Knee and Osteoarthritis Outcome Score.

activities and short sprints.[4,9,26] Among female adolescent soccer players, thigh strain injuries represent 8% to 25% of all acute injuries[15,48] compared with 11% among elite female[17] and 13% to 16% among elite male players.[4,56]

In the present study, a history of a previous hamstring injury was not a risk factor for new thigh injuries, which is in contrast to reports from male soccer.[5,26] Although there was a highly significant reduction in the hamstring function score (HaOS) in players with an injury history at baseline, the functional score did not predict new thigh injuries in this group of players. This may simply be a type II error based on the low frequency of thigh injuries, previous and new, in this player population. But the results may also indicate that the questions forming the HaOS were not sensitive in identifying players with functional limitations. However, it should be noted that the set of questions composing hamstring and groin function questionnaires has not been validated. Also, the fact that we asked the players about previous hamstring injuries but recorded thigh injuries as a group (without distinguishing between, eg, hamstring and quadriceps strains) may have influenced the results.

However, prevention programs for hamstring injuries are recommended and can easily be introduced in soccer training. Eccentric strength training of the hamstring muscles increases hamstring muscle torque[7,39] and reduces the incidence of hamstring strains in elite male soccer players.[4,7,39] Because a low quadriceps to hamstring strength ratio is hypothesized to represent a risk factor for knee injuries,[9] eccentric hamstring training using the Nordic hamstring exercise now has been included in injury prevention programs targeting young athletes as well.[4,38,43,50]

Groin Injuries

As shown in the present study, in which groin strain injuries constituted 6% of all acute injuries, groin strains appear to be less common in female[15,17,48] than in male soccer players.[5,24,36,56] Nevertheless, groin injuries can result in extensive rehabilitation time, and longstanding pain may develop into problems in athletes engaged in sports such as soccer that involve kicking, rapid changes of direction, accelerations, and decelerations.[37]

We found a history of previous groin injury to be predictive in identifying players at risk for new groin injuries. In contrast, function limitations in the groin region (GrOS function score) were not a significant risk factor for new groin strains. However, questions related to pain and symptoms tended to be significant predictors for groin injuries. Reduced flexibility of the abductor muscles is believed to be a risk factor for groin strain injuries,[5,14,53] and there may be a relationship with pain and stiffness reported by the athlete in the function score.

Methodological Issues

A limitation of the study was the response rate. Of the 2020 players included in the intervention trial,[50] only 1430 (71%) completed the questionnaire. This may constitute a selection bias, if players with symptoms were more likely to respond. However, we have compared injury proportions between responders and nonresponders and could not detect any difference in the proportion of injuries to the ankle, knee, thigh, or groin (data not shown).

A weakness of this and most other studies assessing the relationship between previous and new injuries is that injury history relies on player recall. It is well known that recall bias is a concern when relying on retrospective self-reporting of injuries.[13,15,26] The only study to date to avoid this was by Hägglund et al,[26] who conducted a study over 2 consecutive seasons and included prospectively collected injury information to study the relationship to reinjuries.

Prospective injury registration on a monthly basis, which was practiced here, also raises questions on recall bias.[15,26] However, research injury recorders were in close contact with the coaches to avoid missing any injury among the players during the study period. It seems reasonable to expect that although minor injuries were missed, most major injuries would have been recorded with this procedure. Also, we were unable to record individual exposure data, as done by Östenberg and Roos,[44] and therefore could not correct for exposure in the risk factor analyses. The same registration method as in the present study was successfully used by Olsen et al.[43] The reliability and validity of the exposure and injury registration have been examined in detail previously[42] and found to be adequate.

Functional testing of all athletes at baseline could have provided additional and perhaps more objective information about possible risk factors. However, this was neither possible nor the intention of the present study.

Practical Implications

Soccer is a contact sport and requires a variety of skills at different intensities. Running is the predominant activity, and explosive efforts during sprints, duels, jumps, and kicks are important performance factors[12,29,45,57] as well as injury risk situations.[3,6,21]

The strong association observed between previous injuries, reduced function, and new injuries in this young cohort suggests that secondary prevention of reinjuries should be emphasized. More effective strategies are needed to support players and coaches in the treatment and rehabilitation of the original injury, to prevent further injuries. As is true for all injuries, appropriate rehabilitation programs and time to allow the player to become symptom free before returning to play are necessary.[5,25] Also, several studies have now shown that including preventive exercises in training sessions can reduce injury risk significantly.[27,38,43]

Although the specificity of the questionnaire is reasonably high, the sensitivity in predicting new injuries through injury history and reduced function scores is low. This limits the usefulness of the questionnaire because it is highly questionable whether it is worth the effort to have every player on a team complete the form. Only every fourth to every second player who became injured had a positive screening result. Thus, it is not possible to use the questionnaire to target injury prevention programs to athletes at risk. If effective injury prevention methods are established for this player population, it is recommended that these are given to all athletes on the team. Whether it is possible to develop a more sensitive and practical questionnaire to screen for injury is not known. However, based on the results of this study, questions covering pain and joint- and muscle-specific symptoms seem to be essential—at least when a player had reported an injury history. Pain seemed to be a useful indicator for limited function for all 4 specific regions studied in the present study. Therefore, a player who is not able to train without pain or other symptoms from a particular region should be advised to undergo rehabilitation and restrict participation in games, as this probably will increase the risk for a new injury.

CONCLUSION

In this study of youth female soccer, about 70% of the players reported to have had at least 1 previous injury to the ankle, knee, hamstring, or groin on at least 1 side during their sports careers, and these groups reported reduced function related to the injured region at baseline. A history of previous injury and reduced function at baseline were significant risk factors for new injuries to the same region and limb during the season.

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Self-reported psychological characteristics as risk factors for injuries in female youth football

K. Steffen[1], A. M. Pensgaard[2], R. Bahr[1]

[1]*Department of Sports Medicine, Oslo Sports Trauma Research Center, Norwegian School of Sport Sciences, Oslo, Norway,*
[2]*Department of Coaching and Psychology, Norwegian School of Sport Sciences, Oslo, Norway*
Corresponding author: Kathrin Steffen, Department of Sports Medicine, Oslo Sports Trauma Research Center, Norwegian School of Sport Sciences, P.O. Box 4014 Ullevål Stadion, 0806 Oslo, Norway. Tel: +47 2 326 23 21; Fax: +47 23 26 23 07, E-mail: kathrin.steffen@nih.no

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Identifying and understanding injury risk factors are necessary to target the injury-prone athlete and develop injury prevention measurements. The influence of psychological factors on injuries in football is poorly documented. The purpose of this 8-month prospective cohort study therefore was to examine whether psychological player characteristics assessed by a self-administered questionnaire represent risk factors for injury. At baseline, female football players (14–16 years) were asked to complete a detailed questionnaire covering player history, previous injuries, perception of success and motivational climate, life stress, anxiety and coping strategies. During the 2005 season, a total of 1430 players were followed up to record injuries. A history of a previous injury [odds ratio (OR) = 1.9 (1.4; 2.5), $P < 0.001$] increased the risk of a new injury to the same region. There were significant differences in disfavor for previously injured compared with non-injured players for ego orientation ($P = 0.007$), perception of a performance climate ($P = 0.003$) and experienced stressful life events ($P < 0.001$). However, only high life stress ($P = 0.001$) and perception of a mastery climate ($P = 0.03$) were significant risk factors for new injuries. In conclusion, a perceived mastery climate and a high level of life stress were significant predictors for new injuries in a cohort of young female football players.

Background

Football (soccer) is probably the most popular sport worldwide, with a growing interest and an increasing number of female players in particular (FIFA, "big count," 2007). It is a contact sport and challenges physical fitness by requiring a variety of skills at different intensities (Cometti et al., 2001; Reilly & Gilbourne, 2003; Wisløff et al., 2004). Nevertheless, football is also associated with a large number of injuries for both genders.

As injury causation is usually complex, risk factors must be clearly established before interventions can be developed and targeted to injury-prone athletes (Bahr & Holme, 2003; Murphy et al., 2003; Emery et al., 2005). Most studies to date have addressed physical and biomechanical risk factors, e.g. abnormal joint kinetics and kinematics (Cowley et al., 2006; Krosshaug et al., 2007; Sigward & Powers, 2007), joint laxity (Östenberg & Roos, 2000; Söderman et al., 2001a), mechanical or functional instability (Östenberg & Roos, 2000; Söderman et al., 2001a), lower extremity strength (Knapik et al., 1991; Söderman et al., 2001a; Askling et al., 2003), muscular imbalances (Knapik et al., 1991), decreased range of motion (Árnason et al., 2004), previous injuries and inadequate rehabilitation (Tropp et al., 1985; Surve et al., 1994; Árnason et al., 2004; Hägglund et al., 2006).

However, successful performance in sports does not only require the athlete to be healthy and physically fit but also mentally prepared to play (Junge, 2000). Some researchers have hypothesized that certain athletes, as a result of their personality traits, have a particular predisposition toward getting injured (Taerk, 1977; Lysens et al., 1989; Junge et al., 2000).

The literature shows that measurements of sensation seeking, stress-coping strategies, competitive anxiety, behavioral traits and coping of life events seem to have an effect on the risk of sports injury in general (Andersen & Williams, 1988, 1999; Taimela et al., 1990b; Junge, 2000; Gunnoe et al., 2001; Johnson et al., 2005; Schwebel et al., 2007), but only four studies have addressed this issue in football players (Taimela et al., 1990b; Junge et al., 2000; Johnson et al., 2005; Schwebel et al., 2007). Except for one study on 11–12-year-old boys (Schwebel et al., 2007), which did not find aggression or risk-taking behavior to increase injury risk, there is no clear evidence available on the relationship between personality characteristics and injury risk in youth football.

If a relationship between psychological factors and injury risk is established, it may be possible to identify a personality profile typical for the "injury-prone" athlete. Players at risk could then be targeted with injury prevention programs, as for example in a recent Swedish study on elite football players. In a 5-month prospective study, Johnson et al. (2005) identified players at injury risk through a screening with a questionnaire designed for psychosocial risk factors. High-risk players received an intervention that, among other factors, included relaxation and imagery training, which lowered the number of injuries in the intervention group after six sessions and two telephone contacts within 4 months of treatment.

A less studied framework to understand injury risk is a motivational perspective. A social climate that fosters a high level of competitiveness and internal rivalry, which are the characteristics of a performance-oriented climate, may result in a different injury risk compared with a climate that focuses on personal improvement and learning, such as a mastery climate (Ames, 1992). Some support for this was found by Pensgaard and Roberts (2000), who reported that levels of negative stress were significantly higher when athletes perceived a performance climate. A performance climate has also been linked to lower levels of sportpersonship (Miller et al., 2004; Kavassanu, 2006). However, to date, there are no studies that have investigated the possible relationship between motivational indices based on an achievement goal theory and injury risk.

Thus, in addition to examining more traditional stress and anxiety measures, which have revealed promising injury predictive power in the past, we wanted to investigate whether different motivational profiles could help in explaining injury occurrence among young female football players. Based on the revised Stress–Injury model developed by Williams and Andersen (1998), variables targeting both personality (i.e., goal orientations, trait anxiety and coping style) as well as situation (i.e., motivational climate and life events) may be useful to predict new injuries.

The aim of this prospective one-season cohort study involving young female football players was to examine whether psychological characteristics assessed by a pre-season self-administered questionnaire represent risk factors for new injuries. We hypothesized that there would be an increased injury risk among predominantly ego-oriented players, also among players who perceive a performance-oriented climate, and among players with low coping strategies and high levels of life stress.

Material and methods

Study population

This study is based on data from a randomized trial on young female football players examining the effect of a specific training program designed to prevent injuries. The design, the intervention program and the results of the study have been described in detail in a separate report (Steffen et al., 2008a). All teams ($n = 157$) in the southeast region of Norway that had registered to participate in the Under-17 league system in the 2005 season were invited to take part in the study. Of these, a total of 113 teams (72%) volunteered to be included. The competitive season lasted from the end of April until mid-October, interrupted by a 7-week summer break without regular league matches, but with some invitational tournaments. The teams were also followed for 2 months of the pre-season period (March/April). Throughout the season, the teams played 14–24 league matches and trained one to three times a week.

Before the start of the pre-season, the players received written and oral information about the study, and it was emphasized that participation was voluntary. The study was approved by the Regional Committee for Research Ethics, and written consent was obtained. A player was entered into the study if she was registered by the team as participating in the U17 league system, which means that she had to be 16 years or younger. Players who were injured at the start of the study were included from the time they returned to play, but this pre-existing injury was not included in the data analysis.

Risk factor questionnaire

During the 2-month pre-season period, each player was asked to complete a detailed questionnaire covering sports participation, a history of previous knee, ankle, groin or hamstring injuries, as well as present symptoms and function of the lower limbs. However, the last part of this comprehensive questionnaire included questions related to psychological player characteristics that formed the basis for the present paper.

These characteristics were assessed by five established self-evaluation questionnaires, and all questions were chosen to answer one of the given alternatives: first, the Norwegian version (Roberts & Ommundsen, 1996) of the Perception of Success Questionnaire (POSQ) (Roberts et al., 1998) was used to assess task (six items) and ego (six items) goal orientation. Further, the Norwegian version (Roberts & Ommundsen, 1996) of the Perceived Motivational Climate in Sport Questionnaire (PMCSQ) (Seifriz et al., 1992) was selected to assess perceptions of the motivational climate in their team. This instrument distinguishes the training climate in mastery (seven items) or performance climate (11 items). For the POSQ and the PMCSQ, entry was required on a five-point Likert scale. Items were scored from *strongly agree* to *strongly disagree*.

Third, psychological variables connected to a history of stressors were captured by the Life Event Scale for Collegiate Athletes (LESCA) (Petrie, 1992). The LESCA has been adapted from the Swedish version (Johnson et al., 2005). Similar to Gunnoe et al. (2001), the LESCA was modified by excluding 32 from the original 69 items to adapt the LESCA to the young cohort (modified LESCA; excluded question nos. 1–2, 8–11, 13-, 14, 18–20, 22, 27, 30, 36–38, 43, 44, 49, 53, 57, 58, 60–63, 65–69). Fourth, the recently validated Norwegian Sports Anxiety Scale (SAS-n) (Abrahamsen et al., 2006), a multidimensional sport performance trait anxiety inventory, provided three sub-dimensions: somatic anxiety (nine items), worry (seven items) and concentration disruption (five items), respectively.

Entry was required for one out of the two response alternatives (modified LESCA) and on a four-point Likert scale (*strongly agree* to *strongly disagree*) (SAS-n). For both questionnaires, the players were asked to indicate those items of life events (modified LESCA) and stress perceptions (SAS-n), and for each item, to rate its impact (i.e., debilitating or facilitating) at the time of occurrence (*extremely/strongly negative* to *extremely/strongly positive*).

Finally, the Norwegian version (Abrahamsen et al., 2006) of the Brief Cope (Carver, 1997) elicited information on stress coping divided into problem- (10 items), emotion- (14 items) or behavior-focused strategies (four items). Response options on a four-point scale ranged from *I have not been doing this at all* to *I have been doing this a lot*.

The full questionnaire was designed to be read optically, and data were transformed into an SPSS database (SPSS for Windows 15.0, SPSS Inc., Chicago, Illinois, USA). A questionnaire was accepted for scanning if the players had answered to each of the five sub-questionnaires. If a mark was placed outside a Likert box, the closest box was used. If two boxes were marked or a mark was placed between two boxes, that box that indicated the more negative response alternative was chosen. If no mark was placed at all, a missing value for that particular item was transformed and registered in the database. One of the standard procedures of the data program used for the optical reading allowed us and required a personal quality control of the data entry procedures.

For each of the separate sub-dimensions, a mean of the items included was calculated. Based on the maximum sum-score of perceived life stress in modified LESCA (37 points, mean 5 points), players were divided into two groups: players with a low level of perceived life stress (0–5 points) and those with a high stress level (>6 points).

The questionnaire was introduced to the players at a team meeting by staff who were carefully instructed in how the questionnaire should be completed. They were also present to answer questions while the players completed the questionnaire. It was ensured that the players had adequate privacy when answering the questions, and it took them about 60 min to complete the full questionnaire, including 15–20 min for the five psychological sub-questionnaires. Completed questionnaires were missing for players who did not attend the scheduled team meetings and for teams that, for unknown reasons, were unable to arrange team meetings.

Injury registration

To monitor all injuries throughout the 8-month study period, 18 physical therapists were recruited and assigned to the teams (typically five to seven teams each) to record injuries from March 1 through October 31. All coaches were asked to keep a continuous log of all data requested. The coach of each team was contacted by telephone and/or e-mails at least once a month to record new injuries, as well as all playing activities in training and matches. Injured players were interviewed by the injury recorders to assess aspects of the injury based on a standardized injury questionnaire. All information was registered using a web-based recording system.

An injury was registered if it caused the player unable to fully take part in match or training sessions the day following the injury (*time loss* injury) (Fuller et al., 2006). 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. A previous injury was defined as an injury of the same type and the same site as an index injury and that occurred after a player had returned to full participation from the index injury. The location and type of injury were recorded. None of the injured players were examined or treated by any of the authors or the injury recorders involved in the study.

Statistics

This cohort study represents a secondary analysis of data from a randomized-controlled trial (Steffen et al., 2008a). As no differences were seen in injury rates between the intervention and control groups, the analyses did not factor in group assignment.

Descriptive data, such as anthropometrics, player history and scores for the different sub-dimensions within each questionnaire, are presented as mean values with standard deviations (SD). Intercorrelations between all psychological variables were calculated and are presented by Cronbach's α.

Groups of previously and prospectively injured and uninjured players were compared using MANOVA, with the various psychological factors as dependent variables and univariat *post-hoc* analyses when MANOVA was significant. Group differences are presented as P-values. In addition, using logistic regression models with new injury as a dependent variable, and the psychological variables as exposure variables, crude (cOR) and adjusted odds ratios (aOR) were calculated

We calculated relative risk (RR) with 95% confidence intervals (CI) for a one-unit increase in the exposure variable *years of organized football play* and *number of previous injuries*. All regression models were adjusted for the effects of cluster (person and team, using geographic region as a surrogate for team) using Poisson's regression models based on generalized estimating equations (GEE). Similarly, OR with 95% CI were calculated for the groups of players with previous injuries and high levels of life stress vs new injuries.

All tests were two-tailed, and P-values <0.05 were considered to be significant.

Results

Baseline data

A total of 1430 players (71% of the entire cohort) (Steffen et al., 2008a) completed the questionnaire on psychological player characteristics. The mean age of these players was 15.4 years (SD = 0.8, range 13–17), and they had been involved in organized football play for an average of 5 years (SD = 2; 1 to >6). Per limb, the average number of previous injuries to the ankle, knee, hamstring and groin was 1.8 (2.7; 0–16).

Analyses have been performed according to possible interactions between the different psychological variables and the intervention and control groups, respectively. However, no differences were found in the mean values between these two groups and, hence, no interaction effects were observed.

Of the 1430 players, 1003 (70.1%) reported previous injuries to the knee, ankle, hamstring or groin. There were significant between-group differences to the disadvantage of previously injured players for ego orientation ($P=0.007$) and perception of a performance climate ($P = 0.003$), as well as for use of emotion-focused coping strategies ($P = 0.015$). Further, players with an injury history perceived their anxiety reactions to be more debilitating for their performance than did uninjured players ($P = 0.031$) and had, in addition, experienced more stressful life events ($P < 0.001$) (Table 1).

Overall injury characteristics

A total of 296 of the 1430 players (20.7%) sustained at least one injury during the 2005 season. Of these players, 49 (3.4%), 16 (1.1%) and one (0.07%) incurred two, three and four injuries, respectively, leading to a total of 380 injuries. There were 330 acute injuries (Table 2) and 50 overuse injuries. The most common types of overuse injury were anterior lower leg pain (35% of all overuse injuries) and knee pain (21%), while an ankle sprain was the most common acute injury type (111 injuries, 34%). Of the 330 acute injuries included, 70 (21%) were re-injuries.

Risk factors for new injuries

The risk of injury was almost twice as high for players with a previous injury to the same region and site during the study period than for players without an injury history [OR = 1.9 (95% CI 1.4–2.5), $P < 0.001$]. In addition, the number of years of organized football play significantly influenced the risk of new injuries [RR = 1.12 (CI 1.04–1.22) for each additional year of play reported, $P = 0.003$]. The risk of sustaining a new injury increased with the

Table 1. Mean values and standard deviations (SD) for all scales and sub-dimensions within the five questionnaires for previously and prospectively injured and uninjured players

	Previously injured			Injured (2005 season)		
	Yes ($n = 1003$)	No ($n = 422$)	P-value	Yes ($n = 296$)	No ($n = 1134$)	P-value
1. Perception of success						
Task	4.41 (0.65)	4.37 (0.65)	0.33	4.44 (0.64)	4.39 (0.66)	0.26
Ego	2.64 (1.14)	2.47 (1.08)	0.007	2.63 (1.13)	2.58 (1.12)	0.57
2. Motivational climate						
Mastery	4.36 (0.54)	4.33 (0.52)	0.43	4.41 (0.50)	4.33 (0.54)	0.03
Performance	2.59 (0.78)	2.46 (0.74)	0.003	2.54 (0.76)	2.55 (0.77)	0.83
3. Life Event Scale						
Sum score	7.06 (5.35)	4.99 (4.75)	<0.001	7.30 (5.07)	6.21 (5.29)	0.001
Reaction	−0.53 (1.63)	−0.42 (1.88)	0.32	−0.34 (1.61)	−0.54 (1.73)	0.09
4. Sport Anxiety Scale						
Somatic	0.81 (0.54)	0.77 (0.51)	0.18	0.80 (0.53)	0.80 (0.54)	0.97
Reaction	0.16 (1.03)	0.24 (1.03)	0.21	0.22 (1.11)	0.17 (1.00)	0.50
Worry	1.11 (0.68)	1.10 (0.72)	0.76	1.11 (0.68)	1.10 (0.70)	0.89
Reaction	−0.56 (1.09)	−0.41 (1.19)	0.03	−0.50 (1.19)	−0.51 (1.10)	0.88
Concentration	0.66 (0.57)	0.66 (0.57)	0.99	0.71 (0.61)	0.65 (0.55)	0.06
Reaction	0.19 (1.23)	0.28 (1.33)	0.22	0.24 (1.31)	0.21 (1.25)	0.69
5. Brief cope						
Problem	1.41 (0.58)	1.38 (0.58)	0.43	1.41 (0.59)	1.40 (0.58)	0.68
Emotion	1.04 (0.46)	0.97 (0.45)	0.02	1.02 (0.44)	1.02 (0.46)	0.95
Behavior	0.26 (0.37)	0.24 (0.33)	0.43	0.25 (0.35)	0.26 (0.36)	0.64

Table 2. Number and proportion of acute time loss injuries in relation to injury type and location

	Contusion	Sprain	Strain	Dislocation	Fracture	Pain	Other	Total (%)
Head/neck	5	1					8	14 (4.2)
Upper body	9	5	4	1	6		2	27 (8.2)
Lower body	64	135	73	1	1	1	14	289 (87.6)
Hip	4							4 (1.2)
Groin			19					19 (5.8)
Thigh	3		46					49 (14.8)
Knee	19	20	2	1			11	53 (16.1)
Lower leg	12		4				1	17 (5.2)
Ankle	13	111					1	125 (37.9)
Foot (including toe)	13	4	2		1	1	1	22 (6.7)
Total (%)	78 (23.6)	141 (42.7)	77 (23.3)	2 (0.6)	7 (2.1)	1 (0.3)	24 (7.3)	330 (100)

number of previous injuries [RR = 1.08 (1.04–1.12) for each additional previous injury reported, $P < 0.001$]. None of the anthropometric variables (age, height, weight, BMI) or weekly sports participation were significant risk factors for new injuries. The risk of an injury during the 2005 season was 70% increased for players with a high level of perceived life stress compared with those players with a presumed low level of life stress [OR = 1.7 (95% CI 1.3–2.2), $P < 0.001$].

Significant differences in player characteristics for injured compared with non-injured players were observed for motivational climate and life stress (Table 1). A higher level of perceived mastery climate ($P = 0.026$) and life events ($P = 0.001$) significantly predicted new injuries among the young females (Table 3).

Intercorrelations

Descriptive statistics for predictor variables associated with injury risk and Cronbach's α for all measures are presented in Table 4. Except for behavior-related coping strategies (α = 0.57), the intercorrelation coefficients for all sub-dimensions were acceptable, ranging from 0.70 to 0.95.

Of major interest, players with an injury history perceived the motivational climate as performance oriented, and scored positive on ego orientation. Players characterizing themselves as ego oriented scored positive on perception of a performance climate and also on task orientation. Players who perceived a performance climate reported their anxiety reactions as debilitating (somatic, worry and concentration disruption).

There was a moderate, positive association between players with new injuries during the 2005 season and perception of a mastery climate. These players (mastery) were also both task and ego oriented, and interpreted perceived, somatic anxiety as facilitating for performance. New injuries and self-reported previous injuries were strongly correlated to each other, and both new and previous injuries were associated with having experienced a high level of total life stress.

Players who rated low in coping strategies suffered from significantly more life events. However, coping resources were neither correlated to previous (except for emotion) nor new injuries.

Table 3. Logistic regression models for all scales and sub-dimensions within the five questionnaires to predict the risk for new injuries

	c OR	95% CI	P-value	a OR*	95% CI	P-value
1. Perception of success						
Task	1.12	0.92; 1.38	0.26	1.12	0.91; 1.37	0.28
Ego	1.03	0.92; 1.16	0.57	1.02	0.91; 1.14	0.78
2. Motivational climate						
Mastery	1.34	1.04; 1.72	0.03	1.34	1.04; 1.72	0.03
Performance	0.98	0.83; 1.16	0.83	0.94	0.80; 1.12	0.50
3. Life Event Scale						
Sum score	1.04	1.01; 1.06	0.001	1.03	1.01; 1.05	0.02
Reaction	1.07	0.99; 1.16	0.09	1.09	1.00; 1.18	0.05
4. Sport Anxiety Scale						
Somatic	1.00	0.78; 1.27	0.97	0.97	0.76; 1.24	0.81
Reaction	1.05	0.92; 1.19	0.50	1.06	0.93; 1.21	0.39
Worry	1.01	0.84; 1.22	0.89	1.01	0.84; 1.21	0.95
Reaction	1.00	0.90; 1.14	0.88	1.03	0.91; 1.16	0.64
Concentration	1.23	0.99; 1.54	0.06	1.23	0.99; 1.54	0.07
Reaction	1.02	0.92; 1.14	0.69	1.03	0.93; 1.15	0.57
5. Brief cope						
Problem	1.05	0.84; 1.31	0.68	1.04	0.83; 1.30	0.72
Emotion	1.01	0.76; 1.34	0.95	0.96	0.72; 1.28	0.79
Behavior	0.92	0.64; 1.32	0.64	0.89	0.62; 1.28	0.54

Data are presented as crude and adjusted OR with 95% CI.
*Adjusted for previous injuries
OR, odds ratio; CI, confidence interval.

Discussion

The aim of this prospective cohort study on young female football players was to assess self-evaluated player characteristics in relation to injuries sustained during the subsequent season. The principal finding of this investigation was that a perceived mastery climate and high level of life events were significant risk factors for new injuries.

So far, only a few studies have addressed psychosocial stressors and injury risk in different athlete groups (Petrie, 1992, 1993; Junge, 2000; Johnson et al., 2005; Schwebel et al., 2007). There is strong evidence that stressful life events can adversely affect an individual's health (Kelley, 1990), and previous findings have suggested that athletes with high life stress, poor coping skills or low social support appear to be more vulnerable to injury (Blackwell & McCullagh, 1990; Petrie 1992, 1993; Gunnoe et al., 2001). These former findings were partly supported by the present study, where self-reported high life stress was found to be associated with an increased injury risk.

Player characteristics and injuries

Longer football play in organized team activities strongly predicted the risk for new injuries. As also observed by Peterson et al. (2000), one might assume that experienced and better skilled players are protected from injury because they will have developed a greater ability to control themselves by choosing safe and skillful maneuvers on the pitch. In the present young female football teams, the technical, tactical

Table 4. Means, standard deviations (SD) and intercorrelations for all variables

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1. Previous injury	–																	
2. New injury	0.12[a]	–																
3. Task	0.03	0.03	–															
4. Ego	0.07[a]	0.02	0.41[a]	–														
5. Mastery	0.02	0.06[b]	0.34[a]	0.11[a]	–													
6. Performance	0.08[a]	−0.01	0.05	0.33[a]	−0.03	–												
7. Life event-sum	0.18[a]	0.08[a]	0.05	0.11[a]	0.05[b]	0.24[a]	–											
8. Life event-cut	0.18[a]	0.10[a]	0.07[a]	0.08[a]	0.05	0.18[a]	0.77[a]	–										
9. Life event-reaction	−0.03	0.05	0.09[a]	0.02	0.11[a]	−0.16[a]	−0.14[a]	−0.08[a]	–									
10. Somatic	0.04	0.00	−0.03	0.07[a]	0.07[b]	0.21[a]	0.29[a]	0.22[a]	0.15[a]	–								
11. Somatic-reaction	−0.04	0.02	0.13[a]	−0.05	0.08[a]	−0.20[a]	−0.12[a]	−0.07[b]	0.22[a]	−0.41[a]	–							
12. Worry	0.01	0.00	−0.02	0.09[a]	0.03	0.29[a]	0.33[a]	0.29[a]	−0.24[a]	0.71[a]	−0.39[a]	–						
13. Worry-reaction	−0.06[b]	0.00	0.05	−0.05	0.02	−0.20[a]	−0.21[a]	−0.19[a]	0.29[a]	−0.42[a]	0.69[a]	−0.63[a]	–					
14. Concentration	0.00	0.05	−0.12[a]	0.01	−0.05	0.29[a]	0.24[a]	0.18[a]	−0.18[a]	0.59[a]	−0.29[a]	0.59[a]	−0.35[a]	–				
15. Concentration-reaction	−0.04	0.01	0.12[a]	−0.02	0.12[a]	−0.19[a]	−0.12[a]	−0.08[a]	0.25[a]	−0.33[a]	0.70[a]	−0.37[a]	0.61[a]	−0.43[a]	–			
16. Problem	0.02	0.02	0.21[a]	0.08[a]	0.24[a]	−0.02	0.20[a]	0.21[a]	0.00	0.23[a]	0.04	0.22[a]	−0.02	0.10[a]	0.07[b]	–		
17. Emotion	0.06[b]	0.00	0.09[a]	0.07[a]	0.15[a]	0.14[a]	0.30[a]	0.27[a]	−0.13[a]	0.37[a]	−0.11[a]	0.41[a]	−0.20[a]	0.28[a]	−0.10[a]	0.71[a]	–	
18. Behavior	0.02	−0.01	−0.10[a]	0.05	−0.12[a]	0.21[a]	0.16[a]	−.10[a]	−0.17[a]	0.19[a]	−0.14[a]	0.24[a]	−0.17[a]	0.25[a]	−0.17[a]	0.08[a]	0.33[a]	–
Alpha	–	–	0.92	0.84	0.72	0.85	0.84	–	–*	0.89	0.86	0.88	0.88	0.82	0.70	0.84	0.80	0.57
Mean	0.70	0.21	4.40	2.59	4.35	2.55	6.43	–	−0.50	0.80	0.18	1.10	−0.51	0.66	0.21	1.40	1.02	0.26
SD	0.46	0.41	0.65	1.13	0.53	0.77	5.26	–	1.71	0.53	1.02	0.70	1.12	0.57	1.26	0.58	0.45	0.36

[a]$P < .01$; [b]$P < .05$.

*Too few cases for analysis.

and physical abilities seem to vary considerably across a team. The best skilled players may also be those most actively engaged in the game and therefore be most exposed to injuries. Unfortunately, no information about player skill level could be obtained, and this question has to remain unanswered.

Almost one-fourth of all acute injuries recorded in the present study were re-injuries, based on a previous identical injury, which may come as a surprise in such a young player population. However, the explanation seems obvious; as many as one in every five players sustains an injury every season and the injury pattern is quite consistent, with hamstring strains and ankle and knee sprains being by far the most common injuries. Similar injury distributions and high re-injury proportions have also been recorded in other studies on young (Söderman et al., 2001b; Emery et al., 2005), as well as adult female football players (Östenberg & Roos, 2000; Söderman et al., 2001a; Faude et al., 2005; Jacobson & Tegner, 2007). However, this finding may also be taken as an indication of inadequate injury rehabilitation and premature return to play.

It was hypothesized that players characterized as ego oriented and perceiving their climate to be performance involving will be at increased injury risk. These characteristics were present in players with previous injuries, indicating that they presumably felt both internal and external pressure to an early return to play after being injured. Surprisingly, having these player characteristics did not predict for new injuries. Quite the opposite, those young females who suffered from an increased injury risk in the follow-up season described the motivational climate to be mastery involving. There are no prospective studies that have addressed the possible relationship between perception of success (i.e., goal orientations) or perception of a motivational climate and injuries. It could be speculated that a mastery climate in certain team–coach relationships could create an increased perfectionism among players due to a strong emphasis on improvement and development, which may force them into injury risk situations. Hall et al. (2007), for instance, found that high task and ego goals combined with elements of neurotic perfectionism explained 27% of the variance in the obligatory exercise behavior of male college athletes.

However, in another study on Norwegian female football players, data revealed that those players who perceived the motivational climate as predominantly mastery oriented, and who had a moderately positive score on task orientation, scored negative on maladaptive perfectionism (Ommundsen et al., 2005). Thus, more studies are needed that examine the possible negative effects of having a mastery climate combined with high ego and task goals.

A stress response is triggered if an athlete perceives that his or her resources are inadequate to meet the situational demands from, e.g. a motivational climate, and an accumulation of life stress may predispose the athlete to an athletic injury (Taimela et al., 1990a; Williams & Andersen, 1998; Dunn et al., 2001). Stressful life events are one of the most frequently studied psychosocial variables in the area of injury risk, and a greater likelihood of injury was found in high-stress compared with low-stress athletes (Williams & Andersen, 1998; Andersen & Williams, 1999; Ford et al., 2000; Gunnoe et al., 2001).

Similar findings were also seen in the present study, where life stress correlated positively to previous and to new injuries. Interestingly, even though previous injuries have been shown to be a strong predictor for new injuries in this cohort (Steffen et al., 2008b), high levels of life stress significantly increased injury risk independent of an injury history. In contrast to Andersen and Williams (1999), the negative loading of life stress did not further influence injury risk. However, an increase in life stress – regardless of being perceived as positive or negative, as shown by the present results – may also contribute to disruption in concentration and for this reason be perceived negatively. A stress-produced injury is thought to be a generalized physiological arousal that increases muscle tension and reduces motor coordination (Williams & Andersen, 1998). However, there is no direct experimental evidence to support this assumption. It was, however, in some way surprising to see how high life stress can interact with new injuries in a group of such young players. One hypothesis is that these players have reached or already passed the state of puberty. It is well known that puberty can significantly influence a person's hormones and psychosocial state of mood. Moreover, half of the players, the 16 year olds, were close to change school for coming into the high school system. This fact in general, but also the pressure to get high marks, may additionally have increased the stress level.

Former experiences with coping strategies are mostly valuable to handle new stress situations more positively and to contribute to a players' general well-being. In the present study, previously injured players preferred emotion-focused strategies to cope with competition-related stress situations compared with previously uninjured players. Results from American football showed that injured players had fewer coping resources than uninjured players (Blackwell & McCullagh, 1990). Although Petrie (1993) identified coping as a predictor of the number of days absent from training or competition due to injury, varying stress-coping strategies could not predict the risk of new injuries in the present cohort.

Coping strategies continue to be challenging factors as it seems to be simplistic to analyze them as either adaptive or maladaptive (Pensgaard & Duda, 2002). In the future, a more fruitful approach might be to define coping as a positive response outcome expectancy (PROE) as in the Cognitive Activation Theory of Stress (CATS), instead of looking at coping strategies in general (Ursin & Eriksen, 2004). High levels of PROE are, e.g. associated with lower levels of work stress and sick leave in the general population, and even with high performance in a highly stressful environment such as the Olympic Games (Eriksen et al., 2005).

Among the young female players, a relationship between "worry anxiety" and previous injuries was observed, confirming the results from different prospective studies on other types of sport (Blackwell & McCullagh, 1990; Hanson et al., 1992; Petrie, 1993). Among male football players, a lower than average number of previous injuries was related to fewer worries about their performance, less competitive anxiety and peaking under pressure, a lower anger trait and less outward anger (Junge et al., 2000). However, perceived anxiety before the start of the season could not predict new injuries in our cohort of female football players.

Methodological issues

This is the first study in female football concerning the relationship between personality characteristics and injury risk. One obvious and also general limitation of research in sports psychology is the questionnaires and measurement tools available to assess characteristics of interest. Direct comparisons between the present and previous investigations using different tools should be made with caution. Research involving psychological factors and injury risk in (youth) sports is still limited.

A further limitation of the present study was the response rate. About 71% of the players completed the questionnaire, which means that there is a potential for a selection bias. For instance, players with previous injuries and symptoms from the lower limbs may be more likely to respond. However, injury proportions have been compared between responders and non-responders, and any difference in the proportion of injuries to the ankle, knee, thigh, or groin could be detected (Steffen et al., 2008b).

However, compared with most other observational investigations, the sample size is still large. Nevertheless, the observed numerical differences of specific psychological characteristics were small (<0.5 SD) and reached statistical significance only because of the large sample size. Effect sizes (partial η^2 values) were below 0.03.

Another limitation deals with the collection of exposure data. One theory is that extroverted players receive more playing time than introverted players who are low in self-esteem, and will therefore be more likely to get injured due to increased playing exposure (Kelley, 1990). Here, we were unable to record individual exposure data, as done by, e.g., Östenberg and Roos (2000), and therefore could not correct for exposure in the risk factor analyses.

Perspectives

Besides the improvement of physical performance, technical and tactical skills and injury prevention, personality traits of the players in a team will be essential for team success and should be addressed. This study supports earlier investigations by demonstrating that high life stress has an impact on new injuries. In order to attenuate this risk factor among young female football players, coaches must be aware of the total life stress situation of the player.

A positive motivational climate in a team is considered to be favorable to help those players with a high perception of life stress (Pensgaard & Roberts, 2000). However, it may be that in certain situations, a mastery climate can create a strong emphasis on individual improvement and development; a coach should avoid and, if present, buffer high levels of perfectionism among the players. Coaches will also have the responsibility to lessen life- and sports-related stress by creating a positive motivational climate, support improvement in play and playing intensity, concomitant with arranging a realistic ambition level for the team to protect the players from injuries and in the final stage from burnout (Pensgaard & Roberts, 2002; Lemyre et al., 2008). Implementation of cognitive capabilities such as stress-coping strategies may contribute to create a balance between psychological player characteristics and injury risk (Johnson et al., 2005). Further observational studies among young and older players are required to extend the present findings.

In conclusion, in a cohort of young female football players, a perceived mastery climate and high levels of experienced life stress could significantly predict the risk for new injuries.

Key words: youth, soccer, psychology, risk factor, motivational climate, life stress, coping.

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