Oslo Sports Trauma
RESEARCH CENTER

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Injuries in youth female football

Risk factors, prevention and compliance

DISSERTATION FROM THE NORWEGIAN SCHOOL OF SPORT SCIENCES • 2011

ISBN nr 978-82-502-0461-4

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Acknowledgements

The research presented in this thesis is a direct result of one of the best things in the world: teamwork. This thesis would never have seen daylight if it was not for my friends and colleagues at the Oslo Sports Trauma Research Center and Department of Sports Medicine at the Norwegian School of Sport Sciences. In addition, a number of personal friends have contributed to this thesis in different ways. Thus, I would like to thank:

Thor Einar Andersen, MD, PT, PhD. For recommending me for the PhD position. For being not only my mentor, but also my friend. For challenging me on multiple levels, and thus facilitating personal growth. For allowing me to learn just as much about life as about sports medicine and science. For your advice in tough times. For all of this I am forever grateful. When thinking of you, core values such as integrity, respect and ambition come to mind, but also memories of unbridled laughter and joy. You are a warm and caring person, and you must know that I admire and look up to you.

Roald Bahr, MD, PhD, professor. Your achievements in the world of sports medicine are unprecedented. I am truly grateful for being given the opportunity to work under your direction and to see a legend in action on a day-to-day basis. Your academic level and way of coaching your students are second to none, and through all our encounters I have been trying to absorb as much of your vast wisdom and knowledge as possible. I hope some of this is manifested through our manuscripts.

Kathrin Steffen, PhD, for your massive work that created the foundation for Paper I and II, and for all your help and assistance throughout the course of my PhD. I hope you are proud of the work we have done; I know I am.

Agnethe Nilstad, PT, and Hege Grindem, PT, for the fun, yet productive collaboration on Paper II and III, respectively, and for your excellent Master theses that made it easy for us to author the Papers.

Ingar Holme, PhD, professor, for showing me the ropes in statistics and for sharing your wisdom of life.

I also want to express my sincere gratitude to Grethe Myklebust, PT, PhD; Mario Bizzini, PT, PhD; Jiri Dvorak, MD, PhD; Astrid Junge, PhD; Holly Silvers, PT; Birgitte Lauersen; Ellen Blom, PT; Olav Kristianslund; Tone Wigemyr, PT; Monika Bayer; Heidi Merete Pedersen, PT;

Lars Engebretsen, MD, PhD, professor; Truls Straume Næsheim, MD, PhD; Eirik Grindaker; Kristian Gulbrandsen; Mats Jansen; Håvard Nygaard; Frode Raunehaug; Johanne Støren Stokke; Tuva Brattskar Torsrud; Hallvar Waage; Vegar Vallestad and John Andreas Bjørneboe for all the help with the "The 11+" and/or the Norway Cup study. Your contribution was highly appreciated and I am much obliged to you all.

The participating coaches, players and clubs, and the Norway Cup administrators for supporting and facilitating our research. The Oslo Sports Trauma Research Center and the Norwegian School of Sport Sciences, Norway, for the opportunity to carry out the presented research throughout the years of 2005 to 2010. The FIFA Medical Assessment and Research Centre, the Royal Norwegian Ministry of Culture, the South-Eastern Norway Regional Health Authority, the International Olympic Committee, the Norwegian Olympic Committee & Confederation of Sport, and Norsk Tipping AS for supporting our research through generous grants.

All my kind, caring and fun friends at or related to the Norwegian School of Sport Sciences that have made it joyful to go to work every day: Bjørge Herman Hansen, John Andreas Bjørneboe, Tron Krosshaug, PhD; Erik Hofseth; Eirik Kristianslund; Anders Engebretsen, MD, PhD; Elin Kolle, PhD; Jostein Steene-Johannessen, PhD; Lene Røe; Geir Kåre Resaland, PhD; Kjersti Karoline Danielsen; Håvard Moksnes, PT; Ingrid Eitzen, PT, PhD; Johann Knutsen, PT; Marianne Lislevand, PT; Tiina Vidarsdatter Klami; Synne Repp; Oliver Faul; Ingeborg Barth Vedøy; Cathrine Nørstad Engen; Dag Andre Mo; Håvard Visnes, MD, PT; Eivind Andersen; Tone Bere, PT; Tonje Wåle Flørenes, MD, PhD; Yosuke Shima, MD, PhD; Hideyuki Koga, MD, PhD; Mads Drange; Brynjar Saua; Benjamin Matthew Clarsen, PT; Kjetil Århus; Katrine Mari Owe; May Grydeland; Solfrid Bratland-Sanda, PhD; Trine Stensrud, PhD; Ingeborg Hoff Brækken, PT, PhD; Sigmund Alfred Andersen, PhD, professor; Jorunn Sundgot-Borgen, PhD, professor; May Arna Risberg, PT, PhD, professor; Elisabeth Edvardsen; Tone H. Rasmussen Øritsland; Solveig Sunde; Thomas Ingebrigtsen; Marcel Da Cruz; Vidar Andersen; Gyda Kathrine Moan; Vibeke Stave Kristiansen; Anne Mette Rustaden, PT; Silje Stensrud, PT; Karin Rydevik, PT; Annika Storevold, PT; Arnhild Bakken, PT; Sophie Steenstrup, PT; Aleksander Killingmo, PT; Ola Kjos; Paul Thomas Clay; Stefan Randjelovic; Amilton M. Fernandes; Hilde Moseby Berge, MD; Ina Garthe; Marianne Martinsen; Elisabeth Seljetun Ruud; Kristin Skodje; Lene Anette Hagen Haakstad, PhD; Eivind Tysdal; Kristine Bøhn; Odd Willy Støve; Anne Froholdt, MD; Lars Bo Andersen, MD, PhD, professor; Ina Garthe; Fredrik Bendiksen, MD; Matti Goksøyr, PhD, professor; Jan Helgesen; Asbjørn Fredriksen; Tove Riise; Karen Christensen; Torunn Eilin Gjerustad; Thomas Kveum; Sigmund Loland, PhD, professor; Tormod Skogstad

Nilsen; Kari Bø, PhD, professor; Truls Raastad; Sturla Aakre, Marianne Størkson; Britt Elin Øiestad, PT, PhD; Mathias Haugaasen; Bernt Sivert Nymark; Tresor Egholm; Anders Aanstad; Bjørn Thomas Olsen; Dag Kittil Stenklev; Rune Eliassen; Joakim Gaaserud; Anders Farholm; Liv Korsmo; Erlend Halla; Jørgen Flåtene; Kristian Brudeseth Ruud, PT; Martin Engedahl, PT; Morten Johansen, PT; Karoline Steinbekken; Marte Diana Østlien; Asmund Krogh Hjelmeland, PT; Guro Røen; Arnlaug Wangensteen, PT; Hans Graber; Ole Gerard Nodland; Jørn Åke Berthelsen; Nils Helge Kvamme; Jermund Hoem; Vidar Ertesvåg; Ola Eriksrud, PT; Knut Jæger Hansen, PT; Jan Tore Vik, PT.

My best friends from way back: Erling Hisdal, Morten Iversen, Trygve Wangen Tøsse, Harald Andreassen, Erik Hofseth, Vegar Vallestad, Dag Rød Hilland, Stian Lunde, Sjur Ole Svarstad, Ingvild Margrethe Fredsvik, Hedda Røst, Ørjan Furubotn, Jan Erik Soltvedt, Irene Margrethe Soltvedt, Kenneth André Sandvik, Ragnhild Wangen Tøsse, Karina Birkeland Sandnes, Jannicke Bjotveit, Mari Midttun, Borghild Berge, Rune Aldal, Hege Vik Indrebø, Eivind Lundblad, Børge Kvamsdal, Eskil Vethe Herfindal, Jostein Ringheim, Dan Børge Høvik, Kim Andre Njaastad, Bjørn-Eirik Ystaas, Daniel Hilland, Inge Egeberg, Monica M. Sigurdson, Edson David Salazar Mercado, Cankat Demir, Sigve Kvamme. You guys are like family to me and I love you all.

Finally, I would like to thank my family – my sister Nina, my brother-in-law Gudmund, my nephews Thorbjørn and Torunn Jensine, my mom Eva, my dad Bjørn Inge, my stepfather Ingvar, and stepmother Irene for your love and support throughout my life. I love you all.

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

II. Soligard T, Nilstad A, Steffen K, Myklebust, Holme I, Dvorak J, Bahr R, Andersen TE. Compliance with a comprehensive warm-up programme to prevent injuries in youth football. Br J Sports Med 2010: 44: 787-793.

III. Soligard T, Grindem H, Bahr R, Andersen TE. Are skilled players at greater risk of injury in female youth football? Br J Sports Med 2010: 44: 1118-1123.

IV. Soligard T, Bahr R, Andersen TE. Injury risk on artificial turf and grass in youth tournament football. Scand J Med Sci Sports. Epub ahead of print: 24 August 2010. doi: 10.1111/j.1600-0838.2010.01174.x.

Summary

Football is one of the most popular team sports worldwide. Although the positive health benefits of regular physical activity are well-documented, being active also entails a certain risk of injury. In football, studies on female players have reported overall injury rates nearly as high as for their male counterparts. However, identification of injury risk factors and mechanisms can help us implement tailored injury prevention measures for both sexes at all age and skill levels. A comprehensive warm-up program has been designed to prevent the most common injury types in football; injuries to the lower extremities. "The 11+" is a 20-min program consisting of warm-up and physical conditioning exercises aiming to improve strength, awareness and neuromuscular control of static and dynamic movements.

Aims

The main aim of this thesis was to examine the effect of the "11+" injury prevention program on injury risk in youth female football. We also wanted to investigate how teams' and players' compliance and injury risk were linked to their coaches' attitudes towards injury prevention training. In addition, we wanted to examine two potential risk factors for injury in youth football: play on artificial turf, and players' level of skill.

Methods

A total player population of 1892 female players aged 13 to 17 years formed the basis for Paper I-III, whereas 7848 boys' and girls' matches from one of the largest international youth football tournaments, the Norway Cup, formed the basis for Paper IV. A cluster-randomized controlled trial was carried out to prevent injuries (Paper I), while prospective cohort studies were conducted to characterize compliance and attitudes (Paper II), and to examine players' skill-level (Paper III) and play on artificial turf (Paper IV) as potential risk factors. In Paper I we randomized the players to an intervention group, which carried out the "11+" injury prevention program throughout the 2007-season, or to a control group. We also monitored the compliance with the program and interviewed the coaches to identify attitudes towards injury prevention training (Paper II), as well as asked the coaches to assess the skill-level of their players (Paper III). In Norway Cup 2005 through 2008 we recorded the playing surface for all matches (Paper IV). In Paper I-III the coaches reported injuries and individual exposure weekly throughout the study period, and in Paper IV the coaches recorded injuries in each Norway Cup-match.

Main results

During one season, 264 players injured their lower extremities, 121 players in the intervention group and 143 in the control group (RR: 0.71 [0.49-1.03]). There was a significantly lower risk of injuries overall (RR: 0.68 [0.48-0.98]), overuse injuries (RR: 0.47 [0.26-0.85]) and severe injuries (RR: 0.55 [0.36-0.83]) in the intervention group compared to the control group (Paper I). The compliance with the 11+ program was high (teams: 77%, mean 1.3 sessions per week; players: 79%, mean 0.8 sessions per week). Compared to players with intermediate compliance, players with high compliance with the program had 35% lower risk of all injuries (RR: 0.65 [0.46-0.91]). Coaches who previously had utilized injury prevention training coached teams with a 46% lower risk of injury (OR: 0.54 [0.33-0.87]) (Paper II). The results from Paper III showed that players skilled at ball receiving, passing and shooting, heading, tackling, decision-making when in ball possession or in defense, and physically strong players sustained significantly more injuries overall, acute injuries, and contact injuries than their less skilled teammates (RR: 1.50 to 3.19, all $p<0.05$). Our data collection in the Norway Cup (Paper IV) demonstrated that there was no difference in the overall risk of injury (OR: 0.93 [0.77-1.12]) or in the risk of time loss injury (OR: 1.05 [0.68-1.61]) between artificial turf and grass. However, there was a lower risk of ankle injuries (OR: 0.59 [0.40-0.88]), and higher risk of back & spine (OR: 1.92 [1.10-3.36]) and shoulder & collar bone injuries (OR: 2.32 [1.01-5.31]) on artificial turf compared to on grass.

Conclusions

Although the primary outcome of reduction in lower extremity injury did not reach significance, the present study demonstrated that the "11+" warm-up program can prevent injuries in female youth football. This study is the first randomized controlled trial in female youth football with a sufficient participant compliance to show that the injury risk can be reduced by about one third and severe injuries by as much as one half. Our study also indicated that to prevent injuries, sports injury prevention measures need to be acceptable, adopted and complied with by the athletes and sports bodies they are targeted at. Furthermore, while high skill emerges as a significant risk factor for injury in female youth football, playing on artificial turf does not appear to be a risk factor for acute injury in youth football. However, the playing surface seems to be significant for specific injury types.

Introduction

The expansion of female football

Football (soccer) is one of the most popular team sports worldwide. To date there are more than 265 million players and the number of participants is continuing to grow. In particular, the number of female players is increasing rapidly (FIFA, 2007).

Football used to be a sport played exclusively by males. Females were banned from the sport in Europe by the European Football Association in 1921, before the ban was finally lifted in 1971. In 1982, the first European Championship for women was arranged (UEFA, 2005) and in 1991, the first World Cup (FIFA, 2010). Since then, female football has grown to become an elite sport, with a growing number of both amateur players and professional athletes competing on the international level. By 2007, female football players accounted for 10% of all organized football players in the world (FIFA, 2007).

In Norway, a country of 4.8 million citizens, a national elite league for female players was established in 1984. In contrast to male elite football, however, the vast majority of the female elite players in Norway are still only amateurs. Currently, The Football Association of Norway ("Norges Fotballforbund") comprises close to 107 000 female players, which accounts for 29% of all organized players (The Football Association of Norway, 2009). Furthermore, the share of registered female football players continues to increase. From 2001 to 2006, the growth was 22%, with 13- to 19-year olds accounting for the largest increase. Similar trends are seen in other countries such as Germany (DFB, 2009), Sweden, and in the countries belonging to the Confederation of North, Central American and Caribbean Association Football (CONCACAF) (FIFA, 2007), illustrating the tremendous boost in popularity of women's football.

Youth football

The competitive season for Norwegian youth football players starts in the end of April and ends in the middle of October. The number of league matches for each team ranges from 14 to 24, depending on their level of play and geographical region. In addition there are potential post-season play-off matches and tournaments. Similarly to elite football, youth football has become a year-around sport with the pre-season preparation period normally lasting from January to April.

The league schedule includes a six-week summer break without regular league matches, opening for participation in invitational tournaments.

Epidemiology

Frameworks have been outlined to describe the systematic approach needed to build an evidence base for prevention of sports injuries (van Mechelen et al., 1992; Finch, 2006; Van Tiggelen D. et al., 2008; Finch & Donaldson, 2010). In 1992, van Mechelen et al. described how epidemiological sports injury research ideally should follow a four-step sequence (Figure 1). This theoretical account of how to systematically work with injury prevention proved to lay the groundwork for the sports medicine science in the years to come.

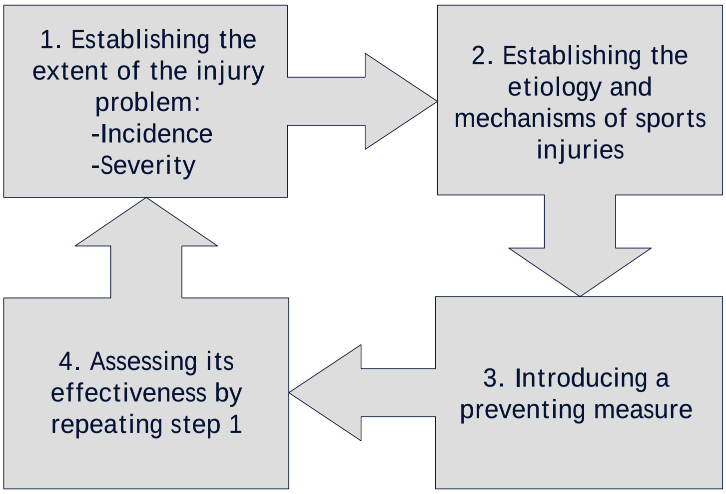

Figure 1. The four-stage sequence of injury prevention research (van Mechelen et al., 1992) (Reprinted with permission from Sports Medicine, Adis International, Wolters Kluwer Health).

However, Finch & Donaldson (2010) recently argued that there were limitations to this approach, exemplified by injury prevention measures that are ”proven” effective in well-designed and scientifically sound studies. However, when such interventions are implemented into the real-world sports context, rather than in the controlled scientific setting, they may not necessarily be effective, typically because they are not used by the target group in the way that was intended. Aiming to direct research efforts towards understanding the implementation context for injury prevention The Translating Research into Injury Prevention Practice (TRIPP) framework was introduced (Figure 2). Particularly, stages 5 and 6 of the model may be important for injury prevention because understanding the barriers and facilitators to the widespread adoption and sustainability of prevention measures may be vital to identifying targets for specific implementation efforts (Finch, 2006).

TRIPP Stage	Research need	Research process
1	Count and describe injuries	Injury surveillance
2	Understand why injuries occur	Prospective studies to establish aetiology and mechanisms of injury
3	Develop “potential” preventive measures	Basic mechanistic and clinical studies to identify what cold be done to prevent injuries
4	Understand what works under “ideal” conditions	Efficacy studies to determine what works in a controlled setting (eg RCTS)
5	Understand the intervention implementation context including personal, environmental, societal and sports delivery factors that may enhance or be barriers	Ecological studies to understand implementation context
6	Understand what works in the “real world”	Effectiveness studies in context of real-world sports delivery (ideally in natural, uncontrolled settings)
Highlighted sections correspond to implementation and effectiveness research needs		

Figure 2. The Translating Research into Injury Prevention Practice (TRIPP) framework for research leading to real-world sports injury prevention (Finch & Donaldson, 2010) (Reprinted with permission from the BMJ Publishing Group).

In the following sections this thesis will synthesize and review the literature on the epidemiology, etiology, and mechanisms leading to football injuries. The review will subsequently assess the studies on injury prevention in female football, as well as compliance and its underpinning determinants. Emphasis will be put on data from female football, but compared with the more extensive literature from male football when appropriate.

Injury definition in football

Like other activities in daily life, playing football entails a certain risk of injury. In the science of sports medicine risk is generally expressed as incidence, which is defined as the number of new cases of an injury/disease (numerator) arising in a defined population in the course of a given period of time (denominator) (Fletcher & Fletcher, 2005). Historically, the incidence of football injury has typically been reported as the number of injuries per 1000 hours of match or training exposure (Inklaar, 1994), and in later years this has become the recommended procedure (Fuller et al., 2006). However, because it has been established in the National Collegiate Athletic Association (NCAA) surveillance system, many North American studies report the incidence as the number of injuries per 1000 athlete exposures. Thus, they do not account for varying duration of the participation when calculating exposure, which makes it an inaccurate measure and complicates comparison to data from other study populations or sports.

While there are many epidemiological studies, variations in definitions and methodology used in injury epidemiology have contributed to differences in their results and conclusions. In some studies, only injuries for which an insurance claim was submitted have been captured (Roaas & Nilsson, 1979; Engebretsen, 1985; Sandelin et al., 1985; Berger-Vachon et al., 1986; de Loës, 1995), whereas in others the definition is confined to injuries in which the player sought medical care (Schmidt-Olsen et al., 1985; Lüthje et al., 1996; Morgan & Oberlander, 2001; Fuller et al., 2004a; Junge et al., 2004a; Giza et al., 2005; Junge et al., 2006; Kiani et al., 2010) or was treated at a hospital casualty department (Klasen, 1984; Høy et al., 1992; Ytterstad, 1996; Goga & Gongal, 2003). By using such definitions, predominantly the severe acute injuries will be recorded. The less serious injuries or overuse injuries may be overlooked, since such injuries do not always require medical attention (Inklaar, 1994; Finch, 1997). Furthermore, amateur and female players do generally not benefit from the same easy access to health care as professional male players, which may bias the injury recording. Also, since the population at risk is often not known, exposure data can only be estimated, which makes it difficult to properly evaluate the injury risk (de Loës, 1997; Finch, 1997).

However, the injury definition most frequently used is based on the absence from football participation. It requires the player to have missed at least one training session or match (Nielsen & Yde, 1989; Ekstrand & Tropp, 1990; Poulsen et al., 1991; Árnason et al., 1996; Heidt et al., 2000; Östenberg & Roos, 2000; Söderman et al., 2000; 2001a; 2001b; Junge et al., 2002; Witvrouw et al., 2003; Árnason et al., 2004b; Ekstrand et al., 2004; Hägglund et al., 2005b; Johnson et al., 2005; Waldén et al., 2005a; 2005b; Jacobson & Tegner, 2007; Waldén et al., 2007; Árnason et al., 2008; Hägglund et al., 2008; Tegnander et al., 2008; Ekstrand et al., 2009; Engebretsen et al., 2009; Hägglund et al., 2009; Hölmich et al., 2009; Werner et al., 2009; Waldén et al., 2010a), or the day(s) following the injury (Hawkins & Fuller, 1999; 2001; Woods et al., 2002; 2003; Andersen et al., 2003; Woods et al., 2004; Andersen et al., 2004d; 2004b; Árnason et al., 2005; Faude et al., 2005; Ekstrand et al., 2006; Faude et al., 2006; Fuller et al., 2007a; 2007b; Steffen et al., 2007; Le Gall et al., 2008b; Steffen et al., 2008b; 2008c; 2009). However, the length of absence from training sessions or matches does not only involve a strong subjective component in each player, it may also be directly affected by the availability of medical treatment, the frequency of sessions, and the importance of the game or player. Furthermore, the definition is sports-, and even position-specific, exemplified by a broken finger that may lead to absence for a volleyball, basketball, or team handball player, but not a football outfield player. Other studies have employed an even wider definition which defines an injury as any tissue damage, regardless of subsequent time loss (Junge et al., 2004b; Waldén et al., 2005a; Junge & Dvorak, 2007; Petersen et al., 2010). Although this potentially may be an objective definition which allows for direct comparison between sports, it generally requires well-trained medical practitioners capable of accurate assessment of injuries. Finally, some authors have used a combination of these injury definitions (Inklaar et al., 1996; Barnes et al., 1998; Emery et al., 2005b; Froholdt et al., 2009; Kraemer & Knobloch, 2009; Meyers, 2010).

In 2006, an international group of scientists and football medicine experts developed a consensus statement, aiming to establish definitions and methodology, implementation and reporting standards for studies of injuries in football (Fuller et al., 2006). In the consensus, an injury was defined as ”any physical complaint sustained by a player that results from a football match or football training, irrespective of the need for medical attention or time loss from football activities”. An injury that results in a player receiving medical attention is referred to as a ”medical attention” injury, and an injury that results in a player being unable to fully take part in future football training or match play as a ”time loss” injury. By standardizing many of the previously used definitions the aim of the consensus statement was to facilitate subsequent comparison of results between studies. However, it has been questioned whether this methodology is adequate when diagnosing overuse injuries, which have a gradual onset. Thus, as an extension to the consensus framework, a novel approach has been outlined to record and quantify the risk and severity of overuse injuries in sport (Bahr, 2009).

In addition to a standardized injury definition, comparison of data between studies also requires a uniform classification of injury severity. Severity can be reported using different criteria: nature and duration of injury, type of treatment, sporting time lost, working time lost, permanent damage, and costs (van Mechelen et al., 1992). However, the most commonly used criterion in football is based on the number of days of absence from match or training due to injury. Although various classification systems have been used (Ekstrand et al., 1983a; van Mechelen et al., 1992), the consensus statement provided a standardization which categorizes injury severity into: slight (0 days, i.e. the day of injury only), minimal (1-3 days), minor (4-7 days), moderate (8-28 days), and major (>28 days) (Fuller et al., 2006).

Recording of injuries and exposure

When conducting epidemiological studies in football, a prospective design is usually superior to a retrospective study. The reliability of retrospective assessments is influenced by the effects of memory such as recall bias (Twellaar et al., 1996; Junge & Dvorak, 2000; Hägglund et al., 2005a; Fuller et al., 2006). Furthermore, a prospective cohort study is also a more powerful study design than a case-control study when aiming to determine the risk factors for injury, since this approach involves measuring potential risk factors before injuries occur, after which new cases and exposure are reported during a period of follow up (Bahr & Holme, 2003). However, in sports where implementation of prospective measurements proves to be impractical, as shown in World Cup skiing and snowboarding (Flørenes et al., 2009), a retrospective approach may be a useful alternative.

The recording of the presence, severity, type, location, and mechanism of injury may also be biased by the injury recorder (Noyes et al., 1988; Crossman et al., 1990; Höher et al., 1997; Junge & Dvorak, 2000; Krosshaug et al., 2007a). Optimally, injuries should be recorded by a medical professional immediately after the event (Fuller et al., 2006). Historically, the team physician or the team physical therapist has been diagnosing injuries (Ekstrand & Tropp, 1990; Árnason et al., 1996; Lüthje et al., 1996; Hawkins & Fuller, 1999; Östenberg & Roos, 2000; Woods et al., 2002; Andersen et al., 2003; Askling et al., 2003; Witvrouw et al., 2003; Woods et al., 2003; Andersen et al., 2004d; 2004b; Árnason et al., 2004b; 2004a; 2004c; Ekstrand et al., 2004; Fuller et al., 2004a; Junge et al., 2004a; 2004b; Woods et al., 2004; Árnason et al., 2005; Faude et al., 2005; Giza et al., 2005; Junge et al., 2006; Waldén et al., 2007; Hägglund et al., 2008; Le Gall et al., 2008b; Tegnander et al., 2008; Ekstrand et al., 2009; Engebretsen et al., 2009; Hägglund et al., 2009; Kraemer & Knobloch, 2009; Werner et al., 2009; Waldén et al., 2010a). However, in some studies injuries are recorded by players or coaches without medical training, which may bias the reliability of the recorded data (Söderman et al., 2000; 2001a; 2001b; Jacobson & Tegner, 2007; Froholdt et al., 2009).

The exposure to the risk factor for injury has been recorded either on a group basis (Myklebust et al., 2003; Meyers & Barnhill, 2004; Giza et al., 2005; Jacobson & Tegner, 2006; Fuller et al., 2007a; 2007b; Jacobson & Tegner, 2007; Steffen et al., 2007; Le Gall et al., 2008b; Steffen et al., 2008b; 2008c; 2009; Tegnander et al., 2008; Froholdt et al., 2009; Petersen et al., 2010; Kiani et al., 2010; Meyers, 2010), or individually (Junge et al., 2000; Peterson et al., 2000; Söderman et al., 2000; Östenberg & Roos, 2000; Söderman et al., 2001a; 2001b; Junge et al., 2002; Árnason et al., 2004b; Ekstrand et al., 2004; Emery et al., 2005b; Faude et al., 2005; Hägglund et al., 2005b; Mandelbaum et al., 2005; Waldén et al., 2005a; 2005b; Faude et al., 2006; Emery et al., 2007; Hägglund et al., 2007; Waldén et al., 2007; Árnason et al., 2008; Engebretsen et al., 2008; Gilchrist et al., 2008; Hägglund et al., 2008; Ekstrand et al., 2009; Engebretsen et al., 2009; Hägglund et al., 2009; Kraemer & Knobloch, 2009; Werner et al., 2009; Waldén et al., 2010a). When recorded on a team basis, the exposure is typically estimated by multiplying the number of players by the hours of training sessions or matches. In this model, it is assumed that participation has been about equal for every athlete. However, this is not always the case, exposure may be reduced because of injury and athletes may leave the team for a number of reasons other than injury. Consequently, exposure is overestimated and the real incidence of injury underestimated. A more appropriate, but also more time-consuming approach is to record the individual exposure of each player (Bahr & Holme, 2003; Hägglund et al., 2005a). The strength of this approach is that the method can adjust for the fact that playing time can vary greatly between players in a team. This may be important, since the best players play more games than the substitutes, and perhaps even train harder. Individual exposure also takes censorship into account, such as abbreviated lengths of follow up for reasons other than injury (e.g. illness, moving, quitting the sport). Furthermore, in intervention studies, this approach is beneficial because it provides accurate data about each player's exposure to the intervention.

Injury incidence in female football

In contrast to male football, relatively few studies have been conducted to address the injury risk in female football, especially among adolescents. Tables 1 and 2 summarize the injury incidences from studies on youth and adult female footballers in league and tournament play.

Youth football

Five studies have reported injury rates among young females playing league football. All were prospective and expressed the injury incidence as the number of injuries per 1000 hours of participation. Söderman et al. (2001a) examined the incidence of acute injuries in 153 players 14 to 19 years of age. Throughout a seven-month season the players sustained 9.1 and 1.5 acute injuries per 1000 match and training hours, respectively. The injuries and exposure were recorded by the players in cooperation with the coaches. Beyond this, the authors provide limited details to allow for an assessment of the reliability and validity of the data collection.

Emery et al. (2005b) conducted a study including both female and male players. Throughout three months they recorded 39 injuries in 164 female players aged 12 to 18 years. The incidence reported was 8.5 and 2.6 injuries per 1000 match and training hours, respectively. However, the study was limited by a low number of injuries due to a short follow-up period and a relatively small sample size. Furthermore, the study included players from several different levels, and it may be questionable whether such a limited sample is representative for the population. The strengths of the study include recording of individual exposure and examination and diagnosis of all time-loss injuries by a physical therapist.

Using data from a randomized controlled trial, Steffen et al. (2007) evaluated the risk of injury on artificial turf and natural grass in 2020 Norwegian players 13 to 17 years of age. The injury rates of the whole sample, irrespective of surface type, were 8.3 and 1.1 injuries per 1000 hours of match and training, respectively. Considering its large size, the results are probably representative for the population. In terms of limitations, the study lacked individual exposure and the injury assessment was conducted through phone interviews.

In a study on French 15- to 19-year olds, le Gall et al. (2008b) documented an incidence of 22.4 and 4.6 injuries per 1000 match and training hours, respectively. This is considerably higher than previously reported, which may partly be explained by an underestimated exposure time, which was calculated per player on an estimate of 10 training hours and 1.5 match hours per week. However, a strength of the study is that all injuries were examined and diagnosed by the same physician.

Froholdt et al. (2009) investigated the injury incidence among Norwegian boys and girls aged 6 to 16 years. Throughout the seven-month season the 298 6- to 12-year old and the 293 13- to 16-year old female players sustained 1.4 and 2.3 injuries per 1000 player hours, respectively. Their data thus suggest that organized football, at least 5- or 7-a-side football for children 12 years or younger, is associated with a very low risk of injury. However, the findings should be interpreted with caution due to low exposure and few injuries among the female players.

In summary, the literature on league play shows an injury incidence in young female football ranging from 4 to 22 injuries per 1000 match hours and 0.4 to 5 injuries per 1000 training hours. Presumably, some of the discrepancy can be attributed to the age and skill level of the players, as well methodological differences in the recording of exposure and injuries.

Tournament play

Injury rates for young females playing tournament football have been reported from three studies, all of which were conducted in the 1980s.

Schmidt-Olsen et al. (1985) examined the injury rates of an international youth football tournament in Denmark. Altogether there were 6600 players 9-19 years of age participating; 1 325 of these were girls. The results showed that the girls sustained 17.6 injuries per 1000 match hours. An identical injury rate was reported by Mæhlum et al. (1986), who recorded injuries in Norway Cup, also one of the largest youth football tournaments in the world. The design and methodology employed in two studies was equivalent, which strengthens the reliability of the findings. Backous et al. (1988) reported a somewhat lower injury rate among 6- to 17-year old girls participating in a summer football tournament in the US. However, while the two Scandinavian studies employed the medical attention-definition, Backous et al. recorded injuries according to the time-loss definition, which is more narrow.

In three separate studies using similar injury recording systems, Junge et al. (2004b; 2006) and Junge & Dvorak (2007) reported data from a number of female international championships. Taking all acute injuries into account, regardless of subsequent absence from play, incidences as high as 39 were found in World Cup matches, while the rates were even higher in the Olympics, with 65 to 85 injuries per 1000 hours (24-49 time-loss injuries per 1000 hours), respectively. Corresponding injury rates were found by Waldén et al. (2007), who reported 36 time-loss injuries per 1000 hours from the 2005 female European Championships.

In summary, injury incidences in tournament matches seem to be higher in senior compared with youth female players. Furthermore, in most youth tournaments during the 1980s, higher injury rates were recorded in girls than for boys (Schmidt-Olsen et al., 1985; Mæhlum et al., 1986; Backous et al., 1988). Whether this is still the case, now that female youth football has matured to a much higher level, is unknown.

Adult football

A 12-month follow-up of 41 elite female players in Sweden reported injury rates as high as 24 and 7 per 1000 match and training hours, respectively (Engström et al., 1991). Similar findings were reported from the German National league, where 115 female players experienced incidences of 23.3 and 2.8, respectively (Faude et al., 2005). Furthermore, the results correspond with data from the female top level in Norway, where 181 players suffered 189 injuries during one season. The incidence of acute injuries was 23.6 and 3.1 per 1000 match and training hours (Tegnander et al., 2008). Somewhat lower match injury rates (13.9 and 16.1) were reported by two recent Swedish studies involving elite players (Jacobson & Tegner, 2007; Hägglund et al., 2008). Similarly, retrospective insurance-based data from the first two seasons of the Women's United Soccer Association (WUSA) professional league showed the injury rate during match and training to be 12.6 and 1.2 per 1000 hours (Giza et al., 2005). Their report corresponds to the results from three studies on Swedish lower level football, which documented incidence rates of 10.0 to 14.3 and 1.3 to 8.4 injuries per 1000 match and training hours, respectively (Östenberg & Roos, 2000; Söderman et al., 2001b; Jacobson & Tegner, 2006).

Compared with elite male football players, the injury rates in female elite football are somewhat lower. In male football, the injury incidence have been reported to range between 16-42 and 1-6 injuries per 1000 match and training hours, respectively (Hägglund et al., 2003; Andersen et al., 2004d; Árnason et al., 2004b; 2005; Hägglund et al., 2005b; Waldén et al., 2005a; 2005b; Fuller et al., 2007a; 2007b; Hägglund et al., 2008; 2009). Fuller et al. (2007a; 2007b) and Hägglund et al. (2008) recorded injuries in both sexes, and found that the female players experienced 57-88% and 81-90% of the male match and training injury rate, respectively. It is uncertain whether the difference in injury rates is caused by differences in level of play or other gender-related factors.

In summary, regardless of age and gender, there seems to be evidence that the risk of match injuries is higher in elite football than on lower levels, whereas the incidence of training injuries is fairly similar between the different levels (Tables 1 & 2). However, the comparison is impeded by study discrepancies in methodology, design, and sample. In fact, direct assessments in male football indicate that teams on higher levels are less prone to training injuries than lower level teams, whereas the relationship between the teams' skill level and the risk of match injuries is unclear (Nielsen & Yde, 1989; Ekstrand & Tropp, 1990; Inklaar et al., 1996; Peterson et al., 2000; Junge et al., 2002).

Table 1. Prospective epidemiological studies on the incidence of injuries (injuries per 1000 hours of participation) in **youth** *and* **tournament female** *football*

Reference Country, year, follow-up	Sample	No of injuries	Injury recording	Injury definition	Injury incidence per 1000 h		
					Match	Training	Total
Youth							
Söderman et al. (2001a) Sweden, 1996, 7 months	n=153 14-19 years	79	Coaches & players, telephone injury assessment by physical therapist	Time loss	9.1 (acute)	1.5 (acute)	4.4 (acute)
Emery et al. (2005b) Canada, 2004, 3 months	n=164 12-18 years	39	Physical therapist & sports medicine physician	Time loss & medical attention	8.6	2.6	5.6
Steffen et al. (2007)[1] Norway, 2005, 8 months	n=2 020 13-17 years	526	Coaches, telephone injury assessment by physical therapist	Time loss	8.3	1.1	3.2
Le Gall et al. (2008b) France, 8 seasons	n=119 15-19 years	619	Team physician	Time loss	22.4	4.6	6.4
Froholdt et al. (2009) Norway, 2005, 7 months	n=619 6-16 years	53	Coaches, telephone injury assessment by physical therapist	Time loss & medical attention	4.6 (acute)	0.4 (acute)	2.0 (acute)
Tournament play							
Schmidt-Olsen et al. (1985) Denmark, 1984, 1 week	Youth n=1 325 9-19 years	117	Tournament medical staff	Medical attention	17.6	-	-
Mæhlum et al. (1986) Norway, 1984, 1 week	Youth n=3 900 <19 years	145	Tournament medical staff	Medical attention	17.6	-	-
Backous et al. (1988) USA, year n/a, 5 one-week sessions	Youth n=458 6-17 years	107	Certified athletic trainer	Time loss	10.6	-	-
Junge et al. (2004b) FIFA World Cup and Olympic Games 3 weeks (WC) & 2 weeks (OG)	Elite n=528 Age n/a	30 (WC) 32 (OG)	Team physician	Physical complaint	38.7 (WC) 64.6 (OG) (24.2 time loss)	-	-
Junge et al. (2006) Olympic Games 2004 Athens, 2 weeks	Elite n=176[2] Age n/a	45	Team physician	Medical attention	70 (30 time loss)	-	-
Waldén et al. (2007) European Championship 2005 England, 2 weeks	Elite n=160 Age n/a	18	Team physician	Time loss	36	2.5	11.6

[1]Only acute match injuries were reported. [2]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.

Table 2. Prospective epidemiological studies on the incidence of injuries (injuries per 1000 hours of participation) in ***adult female*** *football*

Reference Country, season, follow-up	Sample	No of injuries	Injury recording	Injury definition	Injury incidence per 1000 h		
					Match	Training	Total
Adult							
Engström et al. (1991) Sweden, year n/a, 12 months	Elite n=41 21 years	78	Medical students	Time loss	24.0	7.0	12.0
Östenberg & Roos (2000) Sweden, 1996, 7 months	Amateur n=123 14-39 years	65	Physical therapist	Time loss	14.3	3.7	6.6
Söderman et al. (2001b)[1] Sweden, 1998, 7 months	Amateur n=146 20-25 years	80	Coaches & players, diagnosed by physical therapist	Time loss	10.0 (acute)	1.3 (acute)	5.5
Giza et al. (2005)[2] USA, 2001-2003, 2 x 5 months	Elite n=202 Years n/a	173	Team physician	Insurance claim	12.6	1.2	1.9
Faude et al. (2005) Germany, 2003-04, 11 months	Elite n=115 17-27 years	241	Physical therapist & team physician	Time loss	23.3 (acute)	2.8 (acute)	6.8
Jacobson & Tegner (2006) Sweden, 1998, 10 months	Amateur n=253 15-38 years	229	Coaches, telephone injury assessment by author	Time loss	13.3	8.4	9.6
Jacobson & Tegner (2007) Sweden, 2000, 10 months	Elite n=269 16-36 years	237	Coaches, telephone injury assessment by author	Time loss	13.9	2.7	4.6
Hägglund et al. (2008) Sweden, 2005, 10 months	Elite n=228 15-41 years	299	Team physician & physical therapist	Time loss	16.1	3.8	5.5
Tegnander et al. (2008) Norway, 2001, 7 months	Elite n=181 17-34 years	189	Physical therapist	Time loss	23.6 (acute)	3.1 (acute)	6.2

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

The injury pattern in female football

Tables 3 and 4 summarize the injury types and locations from studies on youth and adult female footballers in league and tournament play.

Youth football

Six studies have documented the injury pattern in young female players (Söderman et al., 2001a; Emery et al., 2005b; Steffen et al., 2007; Le Gall et al., 2008b; Yard et al., 2008). Yard et al. (2008) collected injury data from US high schools through an Internet-based sports-related injury surveillance system. Athletic trainers recorded 744 time-loss injuries during two school years, while athlete exposure was recorded in terms of the number of training sessions and matches. Only time-loss injuries requiring medical attention were recorded, which may have lead to an underestimation of the less severe injuries.

Based on these studies, it appears that most injuries in youth female football are acute (72-86%) and affect the lower extremities (79-89%). About half of all injuries are knee or ankle injuries. The most common injury types are ligament sprains (27-35%), muscle strains (6-25%) and contusions (12-32%). Yard et al. (2008) reported that ligament injuries and contusions are the most frequent match injuries, while muscle strains frequently occurred during training. In terms of more specific injury diagnoses two studies have reported that ligament sprains in the ankle predominate (20-26%), as well as ligament sprains in the knee (10-11%) and strains in the thigh and groin (10-11%) (Emery et al., 2005b; Yard et al., 2008). There is a substantial discrepancy in the number of recurrent injuries (4-21%) and less severe injuries (33-72%) reported; this is most likely a result of differing methodology and definitions (Söderman et al., 2001a; Emery et al., 2005b; Steffen et al., 2007; Le Gall et al., 2008b; Yard et al., 2008; Froholdt et al., 2009).

Tournament play

The three investigations from youth tournaments reported similar injury patterns as documented in regular youth league matches (Schmidt-Olsen et al., 1985; Mæhlum et al., 1986; Backous et al., 1988). A slightly different injury pattern has been reported from adult female tournament play, with more head (16-27%) and lower leg injuries (9-20%), as well as a lower proportion of knee injuries (7-16%) (Junge et al., 2004b; 2006; Junge & Dvorak, 2007). However, the latter studies recorded all injuries, irrespective of medical attention or time loss.

Adult football

Studies from adult female and male football have reported a similar pattern of injuries, where acute injuries constitute 65-94% and 69-85% of all injuries (Engström et al., 1991; Árnason et al., 1996; 2004b; Faude et al., 2005; Waldén et al., 2005b; Jacobson & Tegner, 2007). Similar to young female players, injuries to the lower extremity dominate, while the share of recurrent injuries (19-42%) appear to be higher in adult elite and amateur football (Nielsen & Yde, 1989; Árnason et al., 1996; Hawkins & Fuller, 1999; Söderman et al., 2001a; Faude et al., 2005; Jacobson & Tegner, 2007). Compared with their younger counterparts, adult female players also predominantly suffer from ankle and knee injuries, while adult male players experience more thigh and groin injuries (Engström et al., 1991; Lüthje et al., 1996; Hawkins & Fuller, 1998; Hawkins & Fuller, 1999; Östenberg & Roos, 2000; Söderman et al., 2001a; Giza et al., 2003; Faude et al., 2005; Giza et al., 2005; Waldén et al., 2005b; Werner et al., 2009).

In terms of specific injury types, ruptures of the anterior cruciate ligament (ACL) have been found to be more frequent in both adult and youth female players compared with matched males. Female players sustain 0.00 to 0.09 ACL injuries per 1000 hours of training and 0.28 to 2.20 ACL-injuries per 1000 hours of match play (Bjordal et al., 1997; Faude et al., 2005; Giza et al., 2005; Fuller et al., 2007a; 2007b; Hägglund et al., 2008; Le Gall et al., 2008b; Waldén et al., 2010a; 2010b). Furthermore, female players appear to rupture their ACL at an earlier age than do male players (Waldén et al., 2010a; 2010b), and it has been suggested that the risk is especially high in adolescent female players who compete on the adult level (Söderman et al., 2002).

In summary, more than 80% of the injuries in female football affect the lower extremities and mainly occur in the knee, foot and ankle, and thigh. Furthermore, according to the existing literature, acute injuries represent 59% to 90% of the injuries, whereas overuse injuries account for 10% to 41%. However, since overuse injuries occur over time with a gradual onset, the traditional study design using the time-loss injury definition may be inadequate to detect these injuries. It has been shown that different injury definitions and recording methods can lead to different conclusions regarding the rate, severity, and proportion of overuse injuries over a defined time period. For instance, in volleyball, initial data showed that the injury risk, if defined as the incidence of acute time loss injuries, was low (Bahr & Reeser, 2003). However, in a cross-sectional study on the prevalence of the overuse injury jumper's knee in nine different sports, volleyball ranked highest with 45% of players reporting current symptoms (Lian et al., 2005). Lian et al. (2005) concluded that the high prevalence, long duration of symptoms and low function scores suggested that in some sports, overuse injuries such as jumper's knee can cause at least as much impairment for athletic performance as do acute knee injuries. Although the degree to which these findings can be transferred to football – arguably a less technical sport with more physical contact between opposing players – is uncertain, the rationale seems well-founded. Future studies are thus recommended to implement novel methodology developed to record and quantify the risk and severity of overuse injuries in sport (Bahr, 2009).

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

Reference	Söderman (2001a)	Emery (2005b)[1]	Steffen (2007)[2]	Le Gall (2008b)	Yard (2008)	Froholdt (2009)	Schmidt -Olsen (1985)	Mæhlum (1986)	Backous (1988)	Junge & Dvorak (2007)	Junge (2004b)	Junge (2004b)	Junge (2006)	Waldén (2007)
Year	1996	2004	2005	1998-2006	2005-2007	2005	1984	1984	n/a	1999-2006	1999	2000	2004	2005
Follow-up	7 months	3 months	8 months	8 seasons	2 school yrs	8 months	1 week	1 week	4½ weeks	15 weeks	3 weeks	2 weeks	2 weeks	2 weeks
Level of play	Youth	Youth	Youth	Youth	Youth	Youth	Youth	Youth	Youth	Elite	Elite	Elite	Elite	Elite
Age range (years)	14-19	12-18	13-17	15-19	16-18	6-16	9-19	<19	6-17	n/a	n/a	n/a	n/a	n/a
No of players	153	164	2 020	119	416 540	619	1 325	3 900	458	n/a	352	176	176	160
No of injuries	79	47	526	619	744	53	117	145	197	387	30	32	45	18
Injury location														
Head/neck	-	10.6	-	0.5	14.6	5.7	5.1	-	6.5	17.3	33.0	25.0	16.0	5.6
Shoulder/arm/finger	3.8	6.4	-	2.6	6.1	-	6.8	-	3.7	8.3	4.0	9.0	7.0	5.6
Trunk/back	1.9	4.3	-	8.2	4.2	17.0	5.1	-	3.7	8.5	4.0	3.0	9.0	-
Hip	-	10.6	-	0.3	1.6	1.9	-	-	1.3	3.1	-	-	2.0	-
Groin	1.9	-	2.9	9.4	-	0.0	2.6	-	5.1		-	-		-
Thigh	26.9	6.4	12.5	20.7	11.7	5.7	12.8	-	19.0	12.1	8.0	22.0	16.0	16.7
Knee	15.4	23.4	18.7	16.8	21.8	15.1	8.5	-	19.0	11.1	8.0	-	11.0	22.2
Lower leg	5.8	2.1	-	5.0	7.8	1.9	6.0	-	12.7	10.6	25.0	9.0	13.0	22.2
Ankle	34.6	27.7	38.5	25.4	24.7	15.1	22.2	-	22.8	24.0	17.0	22.0	20.0	16.7
Foot	9.6	8.5	-	6.1	6.9	9.4	30.8	-	8.9	3.1	-	-	7.0	11.1
Other	-	-	12.8	-	0.8	-	-	-	2.5	1.8	-	9.4	-	-
Injury type														
Sprain	48.1	36.1	42.9	26.9	29.2	28.3	21.3	25.5	21.4	24.5	15.0	13.0	29.0	16.7
Strain	28.8	19.1	15.1	25.2	17.1	5.7	8.5	-	23.4	8.0	12.0	25.0	9.0	11.1
Contusion	11.5	-	30.8	16.1	-	24.5	31.6	45.5	30.8	42.6	35.0	44.0	36.0	50.0
Fracture	3.8	-	-	3.2	-	3.8	3.4	6.2	-	2.3	8.0	-	2.0	11.1
Concussion	-	4.3	-	-	12.2	-	0.9	-	-	3.1	-	6.0	4.0	5.6
Dislocation	3.8	-	-	0.3	-	-	0.9	-	-	2.1	3.0	-	4.0	-
Other	3.8	40.4	-	15.1	-	9.4	28.2	22.8	22.8	17.3	27.0	12.0	16.0	-
Overuse	3.8	-	11.2	13.2	-	28.3	6.0	-	-	0.8	-	-	-	-

[1]Only acute injuries were reported. [2]Only acute match injuries were reported.

Table 4. 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)	Jacobson & Tegner (2007)	Hägglund (2008)	Tegnander (2008)
Year	n/a	1996	1998	2001-2002	2003-2004	1998	2000	2005	2001
Follow-up	12 months	7 months	7 months	2 x 5 months	11 months	10 months	10 months	10 months	7 months
Level of play	Elite	Amateur	Amateur	Elite	Elite	Amateur	Elite	Elite	Elite
Age range (years)	21 (mean)	14-39	21 (mean)	n/a	17-27	15-38	16-36	15-41	17-34
No of players	41	123	146	202	165	253	269	228	181
No of injuries	78	65	80	173	241	229	237	299	189
Injury location									
Head/neck	-	-	-	10.4	6.6	4.7	5.9	4.9	7.4
Shoulder/arm/finger	-	-	-	7.5	5.3	0.4	1.7	2.0	4.8
Trunk/back	3.8	10.8	-	12.8	7.5	12.7	10.5	9.0	6.9
Hip	-	-	-	5.5	0.8	4.8	7.2	11.4	9.0
Groin	6.4	7.7	3.3		5.4				
Thigh	15.4	17.0	16.4	6.9	18.3	11.4	19.4	23.1	17.5
Knee	23.0	26.2	24.6	31.8	18.7	15.3	24.9	22.1	16.4
Lower leg	9.0	6.2	4.9	6.5	8.2	12.2	10.5	7.0	7.4
Ankle	25.6	10.8	45.9	9.3	17.8	28.4	13.1	16.1	23.8
Foot	9.0	12.3	4.9	9.3	11.2	10.5	6.8	5.4	6.9
Other	7.7	9.2	-	-	-	-	-	-	-
Injury type									
Sprain	33.3	18.5	65.5	19.1	46.5	28.4	24.5	26.8	31.2
Strain	10.3	32.2	16.4	30.7	17.4	6.7	28.7	34.1	36.0
Contusion	15.3	16.9	18.0	16.2	23.7	18.3	8.4	13.4	7.4
Fracture	1.2	3.1	-	11.6	5.4	2.2	1.3	4.1	5.3
Concussion	-	-	-	2.9	-	3.1	3.8	2.4	-
Dislocation	-	-	-	-	-	-	0.8	1.2	-
Other	15.3	7.8	-	-	16.1	0.4	1.7	15.1	9.0
Overuse	28.2	21.5	23.8	16.2	16.2	41.1	31.2	17.7	10.1

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

Injury severity in female football

In terms of injury severity, most injuries in female football are minor or moderate. Although there are differences in the access to professional medical care, the severity distribution of injuries in elite, amateur, and youth football seems to be similar. Table 5 summarizes the findings from studies which have classified the severity in terms of "days of absence from football".

Table 5. Severity of injuries according to the number of days absent from play. Percentages were calculated in relation to all injuries.

Reference	**Level of play**	**No of injuries**	**Severity classification**			
			Minor	**Moderate**	**Major**	
			1-6 days	7-30 days	>30 days	
Engström et al. (1991)	Elite	78	49	36	15	
Faude et al. (2005)	Elite	241	51	36	13	
Östenberg & Roos (2000)	Amateur	65	31	51	18	
Söderman et al. (2001b)[1]	Amateur	80	34	49	18	
Söderman et al. (2001a)	Youth	79	34	52	14	
Le Gall et al. (2008b)	Youth	619	52	36	12	
			1-7 days	8-21 days	>21 days	
Steffen et al. (2007)[2]	Youth	526	44	32	24	
Tegnander et al. (2008)	Elite	189	51	28	21	
Froholdt et al. (2009)[3]	Youth	53	45	34	18	
			Minimal	**Minor**	**Moderate**	**Major**
			1-3 days	4-7 days	8-28 days	>28 days
Jacobson & Tegner (2007)	Elite	237	17	22	39	22
Hägglund et al. (2007)	Elite	266	25	28	34	12
Waldén et al. (2007)	Elite	18	53	0	27	20
Hägglund et al. (2008)	Elite	299	25	28	34	12
Jacobson & Tegner (2006)	Amateur	229	13	39	37	11
			1-3 days	4-7 days	8-30 days	>30 days
Junge et al. (2004b)[4]	Elite	62	50	17	33	-
Junge et al. (2006)[4]	Elite	45	53	26	16	5
			0-1 day	2-7 days	8-14 days	>14 days
Emery et al. (2005b)[3]	Youth	47	36	36	8	21

[1]Only acute lower extremity injuries were reported. [2]Only acute match injuries were reported. [3]Only acute injuries were reported. [4]Severity was estimated based on the expected absence from football.

Injury risk factors

An important step in van Mechelen's (1992) four-step sequence of injury prevention is to establish the causes of injury. This includes obtaining information on why a particular athlete may be at risk in a given situation (risk factors), and how injuries happen (injury mechanisms). Thus, establishing the injury risk factors is essential to identify injury-prone athletes, and, in turn, to develop efficient injury prevention measures (Bahr & Holme, 2003; Murphy et al., 2003; Emery, 2005).

Risk factors have traditionally been categorized as either intrinsic athlete-related factors (e.g. age, gender, weight, skill level) or extrinsic environmental factors (e.g. surface, weather, equipment, coaching) (van Mechelen et al., 1992). However, risk factors can also be classified as modifiable or non-modifiable. Modifiable risk factors (e.g. strength, balance, equipment) can be altered, and are therefore essential for injury prevention. Non-modifiable risk factors (e.g. age, gender, previous injuries) can not be altered, but may still influence the relationship between modifiable risk factors and injury (Meeuwisse, 1991). Furthermore, non-modifiable risk factors can be used to target intervention programs towards individuals at greater risk, e.g. female athletes in the case of anterior cruciate ligament (ACL) injuries.

Meeuwisse (1994) introduced a model to understand the multifactorial causation of sport injuries, where he proposed that intrinsic risk factors are predisposing factors that may be necessary, but seldom sufficient, to provoke an injury. According to his model, the presence of one or more intrinsic risk factors may contribute towards athlete susceptibility to injuries, but both intrinsic and extrinsic risk factors are normally distant from the time of injury and are rarely sufficient to be the lone cause of the injury (Meeuwisse, 1994). Subsequently, Bahr & Krosshaug (2005) introduced a modified version of Meeuwisse's model, adding a more comprehensive description of the inciting event (injury mechanism) (Figure 3). The model provides guidelines for how to account for the events leading to the injury situation (playing situation, player and opponent behavior), as well as the whole body and joint biomechanics leading up to, and at the time of, injury. The notion is that it is the sum of, as well as the interactions between, the risk factors, together with the injury mechanism, that causes the athlete to be injured. Thus, researchers are recommended to record several possible risk factors, and subsequently to combine these in multivariate statistical analyses (Bahr & Holme, 2003; Bahr & Krosshaug, 2005).

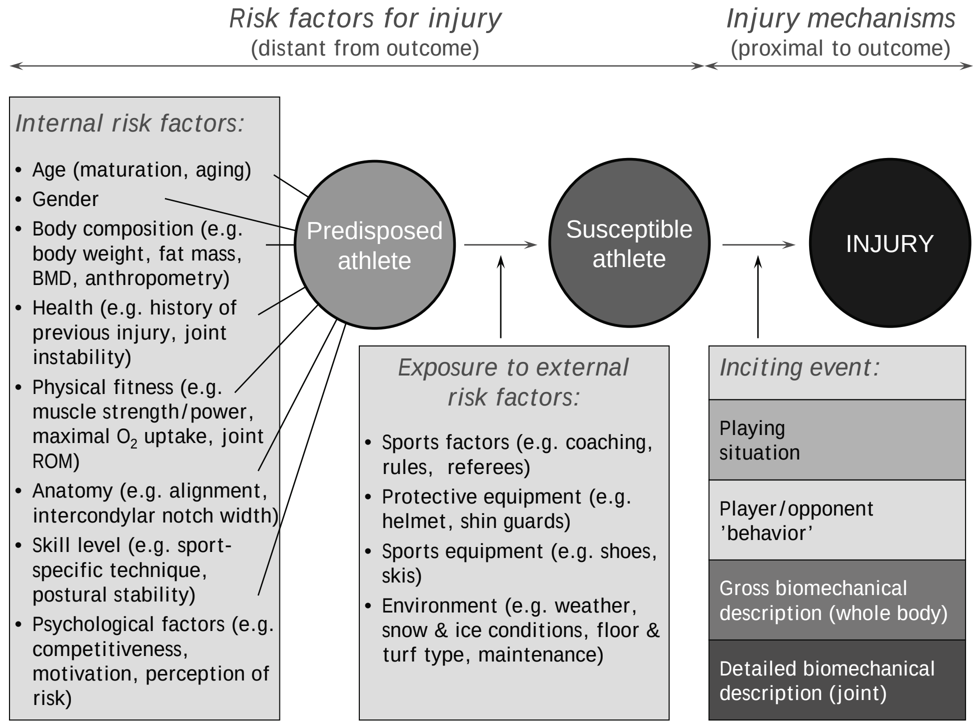

Figure 3. Comprehensive model for injury causation. BMD, Body mass density; ROM, range of motion (Bahr & Krosshaug, 2005) (Reprinted with permission from the BMJ Publishing Group).

However, the focus has recently shifted towards how risk factors can change during exposure. Meeuwisse et al. (2007) introduced a novel dynamic approach that incorporates the consequences of repeated participation in sport, both with and without injury. In order to account for the implications of repeated exposure – whether such exposure produces adaptation, injury, or recovery from injury – risk factors expected to change throughout the data collection period should be object to repeated measurements. If taking the cyclic nature of changing risk factors into account, a dynamic, recursive, and more precise description of etiology can be obtained.

The following section is confined to risk factors linked to 1) the most common lower extremity injuries in female football, as outlined in the epidemiology section, and 2) determinants of football skills. Age, gender, and level of play were discussed in the review of epidemiology, and are omitted in what follows.

Non-modifiable risk factors

Previous injury

A history of previous injury has been suggested to increase the risk of injury in football, often in combination with inadequate rehabilitation and premature return to play. Several explanations have been offered. These include proprioceptive defects (functional instability), muscle strength impairment and imbalance, persistent ligamentous laxity (mechanical instability), and diminished muscle flexibility and joint movement (Murphy et al., 2003). In young female players there seem to be an increased risk of a new injury in the same location in players with a previous injury to the ankle, knee (Kucera et al., 2005; Steffen et al., 2008b), or groin (Steffen et al., 2008b). Furthermore, a history of injury in general also seem to be an injury risk factor (Emery et al., 2005b; Kucera et al., 2005). In senior female football the risk of ACL injury appears to be higher in players with a previous injury to the ligament (Faude et al., 2006). In contrast, no relationship has been found between previous ankle and knee injuries and the risk of new injuries to the same, or other, structures (Söderman et al., 2001b; Faude et al., 2006). In male football, a history of an injury to the same location has been identified as a risk factor for ankle sprains (Tropp et al., 1985; Surve et al., 1994; Árnason et al., 2004b; Kofotolis et al., 2007; Engebretsen et al., 2009), knee sprains (Hägglund et al., 2006; Waldén et al., 2006), and injuries to the groin or hamstrings (Árnason et al., 2004b; Hägglund et al., 2006; Waldén et al., 2006; Engebretsen et al., 2010a; 2010b).

Anatomical alignment of the lower limb

The anatomical alignment of the lower extremities has been discussed widely as a potential risk factor in female football. A relatively wider pelvis, an increased quadriceps angle (Q-angle), and increased genu valgus are all factors suggested to possibly alter lower extremity kinematics, and hence, contribute to an increased injury risk in female players (Shelbourne et al., 1998; Mizuno et al., 2001; Griffin et al., 2006). However, the only study conducted in female football found no association between Q-angle or lower extremity alignment and injury (Söderman et al., 2001b).

Anthropometrics

Another hypothesis is related to anthropometrics, which can be classified as both non-modifiable (height) and modifiable (weight). However, most studies investigating anthropometrics and injury rates find no association. Among female football players only a few studies have been conducted. Steffen et al. (2008b) found no association between age, height, weight, BMI (body mass index) and the risk of injury in young female players. Likewise, no association between BMI and the overall risk of injury was found in a similar sample (Kucera et al., 2005) or in adults (Östenberg & Roos, 2000). The findings from Faude et al. (2006), however, indicated that adult female players taller than 1.75 m, as well as players with a high body weight, were at higher risk of injury. In contrast, Backous et al. (1988) reported that boys taller than 1.65 m had an increased injury risk, but not girls. Two studies from male football reported no difference in height, weight, body composition (% fat), or BMI between injured and uninjured players (Árnason et al., 2004b; Hägglund et al., 2006), whereas Dvorak et al. (2000) found higher injury rates in players with low body fat.

Hormones

The influence of sex hormones has been discussed as a possible risk factor for ACL injuries. Although the epidemiological evidence is contradictory, it has been suggested that hormonal fluctuations during the menstrual cycle is linked to anterior knee laxity, which in turn may affect the risk of ACL injuries. Data from other sports indicate that athletes seem to be more susceptible to injury in both the menstrual phase (day 1 to 7 of the menstrual cycle) (Myklebust et al., 1998; Slauterbeck et al., 2002) and the ovulation phase (Wojtys et al., 2002). An investigation of this relationship in football players reported that compared with the rest of the menstrual cycle, there was an increased risk of injury in the premenstrual and menstrual phases (Møller-Nielsen & Hammar, 1989). Thus, the effect of hormonal changes on the injury risk in female football remains equivocal.

Limb dominance

Faude et al. (2006) reported that significantly more injuries occurred to the dominant leg. In particular, they observed a predominance of overuse, contact, and ankle injuries in the dominant leg. In addition, more ligament ruptures and contusions occurred on the dominant side. Similar observations have been made in male football. Hawkins & Fuller (1999) reported more injuries in the dominant limb overall, whereas Ekstrand & Gillquist (1983a) found ankle injuries to occur more often in the dominant leg. Chomiak et al. (2000) documented that contact knee injuries were more frequent in the dominant leg, but reported no difference in the risk of severe ankle or knee injuries between the dominant and non-dominant leg.

Surface

Whereas professional teams often may have a choice between different playing fields, the options of youth amateur teams are generally much more restricted; hence, surface is listed as a non-modifiable risk factor. Only four studies have examined the relationship between the playing surface and the risk of injury on female football players (Fuller et al., 2007a; 2007b; Steffen et al., 2007; Ekstrand et al., 2010). Steffen et al. (2007) found no difference in the injury rates of 13- to 17-year olds on artificial turf and natural grass. Their results were supported by the findings in female college football from Fuller et al. (2007a; 2007b), who reported an incidence of match and training injuries that was similar on the two surfaces. Likewise, Ekstrand et al. (2010) found no differences between the overall risk, type, or location of injury when playing on artificial turf and natural grass, albeit with a limited dataset in the female sample.

In male football, data from the 1980s and 1990s indicated that the risk of injury on the 1st and 2nd generations of artificial turf was higher than on natural grass (Engebretsen & Kase, 1987; Árnason et al., 1996). In particular, the high incidence of overuse and acute friction injuries was a concern, due to the high stiffness and friction of the surfaces. However, two studies from elite football documented similar injury rates on the 3rd generation of artificial turf and natural grass (Ekstrand et al., 2006; 2010), perhaps an indication of diminishing differences between the surfaces. In terms of acute injuries, corresponding results were reported in a recent study of 12- to 17-year old male players in Japan (Aoki et al., 2010). They found no difference in the risk of acute match or training injuries. However, extended exposure to artificial turf was associated with a higher incidence of low back and chronic pain. This may be an important finding which should be validated in subsequent studies in both female and male football, since chronic pain complaints should be considered an initial warning sign of potential future pathological changes in the body of adolescent players (Bahr, 2009).

Data on injury risk for young females and males playing on artificial turf are lacking, and this question was therefore addressed in Paper IV.

Period of season and match

Studies have indicated a pattern in the seasonal distribution of acute and overuse injuries. Data from female football suggest that pre-season injuries are predominantly overuse, while acute injuries seem to be more common in the competitive season, especially in the beginning and after the mid-season break (Engström et al., 1991; Jacobson & Tegner, 2006; 2007). This is supported by data from male football (Ekstrand & Gillquist, 1983a; Engström et al., 1990; Woods et al., 2002; Waldén et al., 2005a).

With respect to the point in time in which injuries occur during matches, Waldén et al. (2007) reported a higher incidence of non-contact injuries in the second half of women's tournament games. One possible explanation is fatigue, which has been shown to cause alterations in proprioceptive ability and knee mechanics that are associated with common non-contact injuries (Rozzi et al., 1999a; Tsai et al., 2009). Tscholl et al. (2007a) found a similar trend in knockout matches in World Cup-tournaments, where the overall risk of injury was 2.5 times higher the last 15 minutes than in the first 75 minutes of the game. Corresponding results have been reported in male football (Engström et al., 1990; Hawkins & Fuller, 1999; Hawkins et al., 2001; Junge et al., 2004a).

Exposure time

Exposure can be classified as both non-modifiable (number of years) and modifiable (weekly hours). It may seem intuitive that increased exposure is correlated with an equivalent increase in the physiological and cognitive demands, which, in turn, may produce injury (Meeuwisse et al., 2007; Bahr, 2009). However, comparisons can be difficult as injuries result in absence from training sessions and matches, and hence, reduced exposure. Steffen et al. (2008b) reported that years of organized football participation was a significant risk factor for new injuries among young female players. However, weekly participation during the season was not significantly associated with new injuries. This is supported by Emery et al. (2005b), who observed that preseason sports participation did not influence the risk of injury.

Investigations from adult female football have reported conflicting results, as both high overall exposure (Söderman et al., 2001b), low training exposure (Faude et al., 2006), and low match exposure (Faude et al., 2006) have been associated with increased injury rates. The number of years of football participation, however, does not appear to be a risk factor for adult females (Östenberg & Roos, 2000). In comparison, studies on male football have identified low training exposure (Dvorak et al., 2000) and high match exposure (Árnason et al., 2004b) as injury risk factors. Although Ekstrand et al. (1983b) found higher injury rates in teams with a low proportion of training sessions compared with matches, this was not confirmed in a more recent study (Árnason et al., 2004b).

In summary, the evidence from youth female football specifically is poor. Supported by data from other cohorts and sports, possible risk factors for injury seem to be previous injury, anatomical alignment of the lower extremity, increasing age and period of season and match.

Modifiable risk factors

Muscle strength and imbalance

Playing football places great stress on the lower limbs; therefore muscular strength is inextricably linked to successful football performance (Reilly & Doran, 2003; Polman et al., 2004; Stratton et al., 2004). However, in addition to its direct contribution to football performance, it has been hypothesized that muscle strength also may be inversely related to injury risk in sport (Knapik et al., 1991).

For instance, the hamstring muscles control running activities and stabilize the knee (Zakas et al., 1995). In terms of the impact on injury risk, the data of Askling et al. (2003) suggested that low eccentric muscle strength was a significant risk factor for hamstring strains in male football. Corresponding results were presented by Árnason et al. (2008), who found that performing Nordic hamstring lowers, an eccentric exercise shown to increase hamstring muscle strength effectively (Mjølsnes et al., 2004), reduced the rate of hamstring strain injuries. However, there are indications that adult male players incur more hamstring strains than youth players, and to which degree these results are applicable to adolescent female players is uncertain. With respect to concentric isokinetic power in the quadriceps, Östenberg & Roos (2000) did not find this to be a risk factor in adult female players. Similar results were reported by Árnason et al. (2004b) in male elite football.

To date, the effect of muscle strength imbalances on the risk of injury has not been examined among young female players. In adult female football, however, a low hamstring-to-quadriceps strength ratio has been identified as a risk factor for acute lower extremity injuries, while a high hamstring-to-quadriceps ratio was found to predict overuse injuries (Söderman et al., 2001b). These results are complemented by findings from Knapik et al. (1991), who demonstrated that female collegiate athletes were more exposed to lower extremity injury if they had side-to-side imbalances in knee flexor strength or hip extensor flexibility, or a knee flexor/knee extensor ratio of less than 0.75. Furthermore, an investigation from professional male football reported that a low hamstring-to-quadriceps ratio predicted the risk of hamstring injury, and that restoring a normal strength profile decreased the injury risk (Croisier et al., 2008). It has also been suggested that such muscle strength imbalances can be a consequence of previous injury and inadequate rehabilitation (Lehance et al., 2009).

To investigate the effect of strength training on injury risk in youth female football, we included it in our multi-modal injury prevention program tested in Paper I.

Neuromuscular control

Neuromuscular control has been defined as the unconscious efferent response to an afferent signal concerning dynamic joint stability (Lephart et al., 2000). In the lower extremity the influencing factors are knee and ankle kinesthesia and proprioception (joint position sense), postural control (balance), preparatory and reactive muscle activity, and hip and thigh muscle strength (Rozzi et al., 1999b; Lephart et al., 2002a; Pincivero et al., 2003). In addition to the impact on lower extremity joint kinematics and kinetics, improved neuromuscular control can reduce high ground reaction forces that are associated with injury (Lephart et al., 2002a).

The data on neuromuscular control and injury risk from female football are ambiguous. Emery et al. (2005b) did not find any association between players' dynamic balance and injury risk, whereas two studies found higher injury rates in players performing well in a balance test (Söderman et al., 2001b) or a single-leg hop test (Östenberg & Roos, 2000). The authors of the latter study speculated that a confounding variable caused the surprising result. Nonetheless, there are indications that low neuromuscular control may be a risk factor in female athletes (Hewett et al., 2005). Females exhibit a more vulnerable biomechanical profile than males, characterized by greater genu valgus and decreased knee and hip flexion (Lephart et al., 2002b; Ford et al., 2005; Krosshaug et al., 2007b; Pollard et al., 2007). These risk factors are also interrelated; female athletes who limit knee and hip flexion during landing and side-step cutting tasks are more prone to demonstrate genu valgus kinematics (Pollard et al., 2010). By relying more on the passive restraints in the frontal plane to decelerate their body center of mass, such sagittal plane kinematics are thought to increase the risk for severe knee injuries such as ACL tears.

Neuromuscular training was included as a component in our multi-faceted injury prevention program tested in Paper I.

Joint laxity/instability

Generalized joint laxity indicates a generally higher range of motion (ROM) than the mean ROM of the general population, and has been purported as a risk factor for knee ligament injury

(Nicholas, 1970; Acasuso Díaz et al., 1993). Söderman et al. (2001b) explored the relationship between joint instability (among other risk factors) and injury risk in adult female players. The investigators demonstrated a significantly increased risk of injury among athletes with generalized joint laxity and knee hyperextension. These results are supported by another study on female players, applying the same measurements (Östenberg & Roos, 2000). Myer et al. (2008) aimed to identify laxity measures related to the future risk of ACL injury in young female football and basketball players. The authors demonstrated that passive anteroposterior tibiofemoral laxity and passive knee hyperextension could predict ACL injuries in young female football and basketball players. The findings are corroborated by previous studies reporting that excessive generalized joint laxity and knee joint laxity substantially increased the injury risk in a similar population (Rozzi et al., 1999b) and in female military cadets (Uhorchak et al., 2003). Similarly, Ramesh et al. (2005) found that ACL injury was more frequent in those patients with greater overall joint laxity and specifically those with increased knee joint laxity.

It is well known that ACL injury risk in the athletic population is greater in female athletes compared with male athletes. There is also solid evidence that greater knee laxity (Huston & Wojtys, 1996; Rozzi et al., 1999b; Shultz et al., 2007) and increased generalized joint laxity (Larsson et al., 1987; Decoster et al., 1997; Jansson et al., 2004; Seckin et al., 2005; Quatman et al., 2008) are more prevalent in adolescent girls than in their male counterparts. There are indications that decreased dynamic knee stability, mainly resulting from decreased frontal plane knee stability, provides a mechanism that underlies the gender disparity in ACL injury risk (Ford et al., 2003; Hewett et al., 2004; Ford et al., 2005; Hewett et al., 2005; Ford et al., 2006).

In summary, it seems that knee joint laxity could alter dynamic lower extremity motion and loads, which may place ligaments at a higher risk of rupture. Once identified, female athletes who demonstrate decreased knee stability may be targeted with neuromuscular training (Myer et al., 2007). However, more studies are needed to elucidate the real role of joint laxity in the risk of injuries, specifically controlling for other neuromuscular factors.

Flexibility

The literature on muscular flexibility as an injury risk factor in female players is limited. In amateur female football, decreased ROM did not predict muscle strains (Jacobson, 2006) or traumatic leg injuries (Söderman et al., 2001b). However, side-to-side differences in ankle dorsiflexion and hamstring flexibility may predispose for overuse injury (Söderman et al., 2001b). The research from male football provides conflicting results. While three studies found decreased range of motion in hip abduction to predict adductor strains (Ekstrand & Gillquist, 1983b; Árnason et al., 2004b; Ibrahim et al., 2007), no association was found in others (Árnason et al., 1996; Witvrouw et al., 2003). Similarly, the propensity for hamstring and quadriceps strains has been found to be inversely related to the ROM (Witvrouw et al., 2003; Bradley & Portas, 2007; Henderson et al., 2010), while other investigations showed no association between hamstring (Ekstrand & Gillquist, 1983b; Árnason et al., 1996; 2004b) or quadriceps (Ekstrand & Gillquist, 1983b; Árnason et al., 1996) flexibility and subsequent strains. Likewise, male players with a low ankle ROM do not seem to be predisposed to calf muscle injury (Ekstrand & Gillquist, 1983b; Witvrouw et al., 2003).

Warm-up

Since warm-up may provide both physiological (increased performance) and physical (reduced injury risk) benefits, it has become standard practice among athletes prior to participating in sports. For example, warm-up leads to an increase in the speed and force of muscle contractions by speeding up metabolic processes and reducing internal viscosity, which results in smoother contractions (Safran et al., 1989). Also, warm-up produces an increase in muscle temperature. This increase in temperature facilitates the dissociation of oxygen from hemoglobin, providing more oxygen to working muscles. The speed of nerve transmission may also increase with the increase in temperature, which may, in turn, increase contraction speed and reduce reaction time. In addition, the temperature increases that accompany warm-up lead to vasodilation, which produces an increased blood flow through active tissues (Agre, 1985; Shellock & Prentice, 1985; Safran et al., 1989; McArdle et al., 2010). Finally, there are indications that a warm-up provides a protective mechanism to muscle by requiring a greater length of stretch and force to produce a tear (Safran et al., 1988). These changes result in an increased muscle length and greater range of motion (O'Sullivan et al., 2009), which potentially may lead to a reduction in the risk of musculotendinous injuries during athletic tasks. In addition, the increase in neural transmission speed may improve reaction time and thus allow athletes to avoid injurious twists, falls, or tackles (Woods et al., 2007).

Although the theoretical rationale for warm-up seems well-founded, relatively few researchers have explored whether inadequate warm-up is a risk factor in football. While no studies have been conducted in female football, Dvorak et al. (2000) observed that male players with severe injuries performed inadequate muscular warm-up more often than uninjured players. The results are complemented by Ekstrand et al (1983b) who reported that that all quadriceps injuries occurred in teams that were shooting at the goal prior to warm-up, thus providing a plausible link between a lack of warm-up and occurrence of muscle injury.

In Paper I, we tested the effect of warm-up in combination with physical conditioning on injury risk in youth female football.

Playing position

It has been discussed whether certain playing positions may be associated with more potentially hazardous situations, and hence, an increased risk of injury. Two studies conducted among young female players indicate similar injury rates across the different playing positions (Kucera et al., 2005; Le Gall et al., 2008b). In terms of injury locations, however, Le Gall et al. (2008b) reported that defenders predominantly injured their ankle, whereas midfielders and strikers incurred more knee injuries. Among female adults defenders and strikers have been found to suffer from more injuries than goalkeepers and midfielders (Faude et al., 2006; Jacobson & Tegner, 2007; Tegnander et al., 2008), while other studies have not reported such a pattern (Engström et al., 1991; Hägglund, 2007). Finally, in male football there is no evidence to support the hypothesis of playing position being an injury risk factor (Ekstrand & Gillquist, 1983b; Engström et al., 1990; Hawkins & Fuller, 1998; Chomiak et al., 2000; Morgan & Oberlander, 2001; Bradley & Portas, 2007). However, goalkeepers appear to be more exposed to head and upper extremity injuries (Lindenfeld et al., 1994; Dvorak & Junge, 2000).

Equipment

Prospective studies examining the effect of protective equipment are non-existent in female football. The protective effect of ankle bracing and taping has been indicated by one retrospective study, although only for players with previous ankle injuries (Sharpe et al., 1997). However, the finding is complemented by data from male football showing that wearing tape or an ankle orthosis can contribute to a reduction of injuries (Ekstrand et al., 1983a; Tropp et al., 1985; Surve et al., 1994). Although the effectiveness of specific headgear in football is inconclusive (Withnall et al., 2005; Tierney et al., 2008), it has been found to reduce the risk of concussions and injuries to the face in female players (Delaney et al., 2008). However, headgear is rarely used in football.

Foul play

Foul play is a considerable injury risk factor in football. Data from adolescent female football is non-existent, but 19 to 23% of all injuries in adult elite female players can be attributed to foul play (Faude et al., 2005; Jacobson & Tegner, 2007). The rates are similar in male football, with 18 to 31% resulting from foul play (Engström et al., 1990; Lüthje et al., 1996; Hawkins & Fuller, 1999; Andersen et al., 2004b; Árnason et al., 2004c; Junge et al., 2004a). Potential measures to reduce injuries resulting from foul play may include modification and enforcement of the Laws of the Game, the referees' interpretation of the rules, as well as the coaches' and players' attitudes towards fair play and high-risk game situations (Andersen et al., 2004a; 2004b; 2004c; Árnason et al., 2004c; Fuller et al., 2004a; 2004b).

Technical skills

There are no studies investigating the relationship between technical skills and injury rate in young female football. A study of 264 male players from eight different levels and age classes reported no association between injury risk and performance (Dvorak et al., 2000) in eight technical football tests (Rösch et al., 2000). However, the study did not adjust for the exposure time, which compared with the lower level teams was twice as high in the teams at the higher level (Peterson et al., 2000). In contrast to the results of Dvorak et al., Severino et al. (2009) found that being skilled in the technical attributes ball juggling and dribbling was a risk factor for injuries in 11- to 12-year old male players.

In Paper III, we examined whether technical skills can be identified as a risk factor in youth female football.

Tactical skills

Studies investigating whether the tactical decisions of players influence their injury risk are non-existent. We therefore studied the relationship between players' tactical skills and injury rates in Paper III.

Endurance

Emery et al. (2005b) found no association between the risk of injury and the endurance of female and male footballers 12 to 18 years of age. The result may be influenced by low statistical power, as only 26 injuries were included in the analysis. In this study, maximal O_2 uptake was measured using an indirect continuous multistage fitness test. Östenberg & Roos (2000) used the same protocol on female players aged 14 to 39 years and did not find any association between endurance and injury risk. Similar results have been reported from male football, where neither Dvorak et al. (2000) nor Árnason et al. (2004b) found endurance to influence the risk of injury.

Speed & agility

There exists no literature on speed and agility as risk factors for injury in football. The lack of data on the influence of physical attributes on the risk of injury in youth female football led us to address this issue in Paper III.

Psychological factors

Only a few studies have investigated psychological risk factors in female youth football. Moreover, the existing studies have only looked at components such as personality traits or states, whereas cognitive skills, such as anticipation and perception, are yet to be explored. Nonetheless, investigations indicate that psychosocial stressors may be associated with injury rates among adolescent female players (Steffen et al., 2009) and adult female and male players (Dvorak et al., 2000; Johnson et al., 2005). In addition, Steffen et al. (2009) identified perceived mastery climate as a significant injury risk factor, while perception of success, competitive anxiety, and stress coping skills had no influence on the occurrence of injury. Similarly, competitive anxiety, stress coping skills, as well as anger-trait, has not been found to predict injuries in male football (Dvorak et al., 2000). Johnson et al. (2005) screened potential psychological risk factors in 235 female and male players elite players in Sweden. Thirty-two players who were identified as having high injury-risk profiles were subsequently randomized to either an intervention group or a control group. After six to eight cognitive-behaviorally based brief treatment sessions the intervention players experienced a significant injury reduction compared with the control players.

Kontos et al. (2004) studied a cohort of 260 (112 female, 148 male) football players aged 11 to 14 years in a 3-month prospective injury study where the purpose was to determine the predictive validity of psychological variables like self-reported perceived risk, risk taking, estimation of ability, and over-efficacy. It was shown that perceived risk and estimation of ability represented significant psychological risk factors, as low levels of perceived risk and estimation of ability were associated with a significant increase in risk of injury. In contrast, Schwebel et al. (2007) prospectively examined behavioral risk factors (inhibitory control, aggression, risk taking) for youth football injury. Sixty 11- and 12-year old male players were followed over one football season. Through self-report measures from coaches, parents, and the players themselves, the investigators found that neither of the behavioral personality components emerged as predictors of injury. However, due to a low number of injuries the authors used the risk situations fouls, collisions, and falls as proxy measures for injury. Similarly, Kontos et al. (2004) only registered 21 injuries. Thus, the results should be evaluated with caution until they are validated in subsequent studies with larger samples.

In summary, there are few prospective risk factors studies on females in general and equivocal data with respect to which risk factors may be particularly salient. The latter may partly be attributed to small sample and effect sizes, as well as inaccurate measurement tools (Bahr & Holme, 2003; Murphy et al., 2003). Furthermore, since injury causation is multi-factorial, it is necessary to implement a multivariate approach to properly evaluate risk factors for sports injuries. To date, only four studies have examined multi-factorial causality of football injuries in female football; two prospective studies on adult female players (Östenberg & Roos, 2000; Söderman et al., 2001b), one on youth female players (Steffen et al., 2009), and one study using both prospective and retrospective data from female and male youth players (Kucera et al., 2005). Instead, risk factors are typically evaluated separately, and even if multiple potential risk factors have been recorded (e.g. age, gender, skill level, previous injuries, etc.) they are often analyzed in an inadequate univariate manner.

Looking at the overall literature from football and other sports, previous injury, anatomical alignment of the lower extremity, increasing age, period of season and match, low muscle strength, low neuromuscular control, decreased flexibility, joint instability, foul play, level and type of play, and certain psychological factors seems to be potential risk factors for injury.

Injury mechanisms

The term injury mechanism refers to how injuries happen. A complete description of the mechanisms for a particular injury type in a given sport needs to account for the events leading to the injury situation (playing situation, player and opponent behavior), as well as to include a description of whole body and joint biomechanics at the time of injury (Bahr & Krosshaug, 2005).

Recording of injury mechanisms

A variety of different approaches can be used to depict the injury mechanisms, however, no single method exists that can provide a reliable, valid, and complete description of the injury mechanisms in sport (Krosshaug et al., 2005). Thus, it is recommended that injury mechanism assessments employ more than one approach. However, such studies are scarce. Many studies have recorded the data through athlete interviews (Emery et al., 2005b; Steffen et al., 2007; Yard et al., 2008), a method in which recall bias contributes to reduced reliability. In adult football several studies have used video analysis (Andersen et al., 2004a; 2004c; 2004d; Árnason et al., 2004c; Tscholl et al., 2007a), which provides more detailed and reliable data about the playing situation and the athlete/opponent movements. An limitation, however, is that injuries that occur out of camera view, or without a visible trauma, are not recorded (Krosshaug et al., 2005). Furthermore, in contrast to adult male football, female and youth football is often not broadcasted on television networks, which restricts the feasibility of video analysis in these populations.

Reporting of injury mechanisms

With respect to the reporting of injury mechanisms, the inciting event is often discrepantly classified from one study to another, which makes comparison difficult. Most studies use a gross classification of injury mechanisms, i.e. ”contact” or ”non-contact” (Arendt & Dick, 1995; Heidt et al., 2000; Junge et al., 2004b; Agel et al., 2005; Emery et al., 2005b; Faude et al., 2005; Junge et al., 2006; Dick et al., 2007; Hägglund et al., 2007; Steffen et al., 2007; Tscholl et al., 2007a; Yard et al., 2008; Froholdt et al., 2009; Waldén et al., 2010a). Some authors have also provided additional information about the circumstances of the contact situation, such as ”contact with another player” (Hägglund et al., 2007; Tscholl et al., 2007a; Yard et al., 2008), ”contact with another player or equipment” (Emery et al., 2005b; Yard et al., 2008), or ”contact with a player, surface, or other” (Arendt & Dick, 1995; Dick et al., 2007; Yard et al., 2008; Waldén et al., 2010a). In order to provide a more detailed delineation of the injury mechanism, a few recent studies have also reported the player (Steffen et al., 2007; Yard et al., 2008; Froholdt et al., 2009) or opponent (Yard et al., 2008) activity at the time of injury (running, tackling, heading, etc).

In the following, the literature on injury mechanisms in football is reviewed. Emphasis will be put on studies which have used video analysis, since these studies seem to provide the most detailed and reliable data. Data from youth female football will be reviewed and compared with the more extensive literature from adult male football.

Injury mechanisms in football

Youth football

In young female football only four studies have reported injury mechanisms (Emery et al., 2005b; Steffen et al., 2007; Yard et al., 2008; Froholdt et al., 2009). All the studies used athlete interviews, and the reliability of the findings may thus be reduced by recall bias. According to these studies, 40 to 51% of all injuries are contact injuries. Steffen et al. (2007) reported that two out of three acute match injuries were contact injuries, and that more than half were caused by tackles. A slightly more detailed description of injury mechanisms were presented by Yard et al. (2008). They found that complete knee ligament sprains most often resulted from non-contact situations (57%), while player-to-player contact was the most common mechanism for incomplete knee ligament sprains (70%). Player activity at the time of injury was evenly distributed. Most injuries occurred during general play (21%), ball handling/dribbling (14%), chasing a loose ball (14%), and defending (14%). The numbers were similar for boys. Both girls and boys had different injury mechanisms in match and training. In matches, contact injuries were most common, and the players were often injured when defending, heading the ball, receiving a slide tackle, or chasing a loose ball. Among the girls 13% of the match injuries were also related to rule violations. The training injuries, however, were mainly non-contact and related to physical conditioning or general play.

Adult football

In adult female football there is only one study based on video analysis (Tscholl et al., 2007a). The authors found that as many as 86% of all injuries resulted from contact, which may be explained by the video analysis approach, a broad injury definition, and that they investigated international top-level tournament play. Furthermore, more injury events involved tackles from the side (52%) than from the front (38%) or behind (11%). In studies using athlete interviews the proportion of contact injuries has varied from 26 to 75%, which may be attributed to discrepancies in definitions, methodology, and sample (Östenberg & Roos, 2000; Faude et al., 2005; Hägglund et al., 2008; Dick et al., 2007). Dick et al. (2007) reported that contact injuries occurred twice as often in matches as in training sessions. This corresponds to the findings of Yard et al. (2008). Studies have also shown that 45 to 46% of all injuries occur while the player is in possession of the ball, and that 16 to 23% of the injuries are related to rule violations (Faude et al., 2005; Jacobson & Tegner, 2006; 2007; Hägglund et al., 2008).

In male football several authors have used video analysis to evaluate the injury mechanisms, showing that the majority of the injuries occur in player-to-player duels (Hawkins & Fuller, 1999; Rahnama et al., 2002; Andersen et al., 2004a; 2004c; 2004d; Árnason et al., 2004c). In matches, this is manifested mainly in situations where the player receives or makes a tackle, while aerial challenges, collisions, and goal keeper charges are related to a smaller proportion of the injuries. In contrast, most of the training injuries occur when shooting, tackling, cutting, and sprinting.

With respect to specific injury types, the most frequent mechanism for head injuries seems to be elbow to head contact, followed by head to head contact in heading duels (Andersen et al., 2004a; Fuller et al., 2005). The available data suggest that in the majority of the elbow to head incidents, the elbow is used actively at or above shoulder level (Andersen et al., 2004a), and that such unfair use of the upper extremity is more likely to cause an injury than any other player action (Fuller et al., 2005). Most ankle injuries, however, occur in player-to-player contact with either 1) impact by an opponent on the medial aspect of the leg, resulting in a laterally directed force causing the player to land with the ankle in a vulnerable, inverted position; or 2) forced plantar flexion where the injured player hit the opponent's foot when attempting to shoot or clear the ball (Andersen et al., 2004c). With respect to knee injuries, it is ACL injuries that have received most attention. A summary of the literature shows that common inciting events for non-contact ACL injuries include: change of direction or cutting maneuvers combined with deceleration, landing from a jump in or near full extension, and pivoting with knee near full extension and a planted foot. The most common non-contact ACL injury mechanism include a deceleration task with high knee internal extension torque (with or without perturbation) combined with dynamic valgus rotation with the body weight shifted over the injured leg and the plantar surface of the foot fixed flat on the playing surface (Alentorn-Geli et al., 2009). The majority of hamstring injuries in football seem to occur whilst players are running or sprinting (Árnason et al., 1996; Woods et al., 2004). Neuromusculoskeletal models have shown that peak hamstring stretch and force occurs during the late swing phase of the running gait cycle and that force increases significantly with speed

(Thelen et al., 2005; Chumanov et al., 2007). During sprinting hamstring injuries seem to occur in the late swing phase, where the hamstrings work eccentrically to decelerate knee extension which means that the muscles develop tension while they are being lengthened (Heiderscheit et al., 2005; Schache et al., 2009). However, the potential for hamstring muscle injury also exists during the late stance phase in sprinting due to forceful eccentric hamstring muscle contraction at long muscle-tendon length (Yu et al., 2008).

In terms of foul play, investigations have shown that only 12 to 31% of all injuries are awarded a free kick by the referee, and that 76 to 100% of the free kicks are awarded in favor of the injured player (Engström et al., 1991; Lüthje et al., 1996; Hawkins & Fuller, 1999; Andersen et al., 2004b; Árnason et al., 2004c; Junge et al., 2004a; Hägglund et al., 2008).

In summary, we have limited knowledge about specific injury mechanisms in female football. Supported by data from male football, contact with another player seems to be a mechanism of the majority of ankle and head injuries, while the majority of knee and hamstring injuries seem to be non-contact. However, as there are evident differences in injury rates and patterns, as well as in level and style of play (Kirkendall, 2007), between female and male football, it is uncertain whether injury mechanism data from male football are applicable in females.

Injury prevention

Following an increasing awareness of the negative aspects of football participation, there has in recent years been an equivalent increase in the research on injury prevention. Altogether, 27 studies testing the effect of different injury preventive strategies have been conducted. The data from male football is more extensive than in females; ten studies have been conducted in female football, compared with 15 studies from male football. Two studies have looked at both sexes. Since Ekstrand et al. (1983a) reported that a multi-modal prophylactic program reduced the injury risk by 75% in male senior football, more recent studies have evaluated a spectrum of prevention approaches ranging from orthoses (Tropp et al., 1985; Surve et al., 1994; Sharpe et al., 1997), protective headgear (Delaney et al., 2008), balance training (Caraffa et al., 1996; Söderman et al., 2000; Kraemer & Knobloch, 2009), eccentric hamstring strength training (Askling et al., 2003; Árnason et al., 2008; Croisier et al., 2008), video-based awareness (Árnason et al., 2005), and multi-faceted exercise programs (Junge et al., 2002; Hägglund et al., 2007; Engebretsen et al., 2008). Table 6 summarizes the injury prevention studies in female and male footballers. Eighteen of the approaches demonstrated a reduction of either the primary or secondary injury outcomes. However, a number of the studies are limited by poor research designs or inadequate sample sizes; weaknesses that may restrict the validity of the findings.

Female football

We do not know whether the data from male football are transferable to females. To date, there are ten studies published on female football players alone; seven among adolescents. Although some of the studies provide promising prospects for injury prevention, the majority are characterized by either methodological limitations or equivocal results.

Aiming to examine the influence of neuromuscular training on the risk of knee injuries, Hewett et al. (1999) prospectively followed a cohort of female team sport athletes, in which 290 of 829 participants were football players. The players were allocated into an intervention group and a control group, and followed for one season. The authors found that the players in the intervention group experienced a reduction of severe knee injuries approaching statistical significance, and a significant decrease in non-contact knee injuries. In a similar study, Heidt et al. (2000) evaluated the effect of a pre-season conditioning program among female football players 14 to 18 years of age. A total of 300 players were followed over a 1-year period, and 42 of these players participated in a 7-week training program before the start of the season. The training program consisted of warm-up exercises, sport-specific cardiovascular conditioning, plyometric work, ”sport cord drills”, strength training, and flexibility exercises. The results showed that the training group experienced significantly fewer injuries than the control group, and it was concluded that prevention of football injuries should focus primarily on conditioning of the lower extremity in sport-specific activities. However, the results of these two studies should be evaluated with caution, because the studies are restricted by either non-randomized designs or a low number of injuries.

In a prospective randomized intervention study over one football season, Söderman et al. (2000) examined the effect of proprioceptive balance board training among 221 senior female football players. The players were randomized to training on a balance board daily for 30 days, then three times a week during season, or to a control group training as normal. The results showed no significant differences between the intervention and control groups with respect either to the number, incidence, or type of acute injuries to the lower extremities. One important limitation with the study is that the statistical power was low. Nevertheless, the results indicate that balance board training, at least based on a home training program, may not be sufficient to prevent ACL injuries. However, in contrast to these results are the data from other cohorts which suggest that wobble board and balance mat training can both increase dynamic balance and reduce the incidence of injuries in the ankle and knee (Caraffa et al., 1996; Holm et al., 2004; Verhagen et al., 2004; Emery et al., 2005a), especially if implemented in multi-faceted training programs (Wedderkopp et al., 2003; Hrysomallis, 2007).

Mandelbaum et al. (2005) did a prospective, non-randomized trial among female football players aged 14 to 18 years over two seasons, where the intervention group used an multi-faceted exercise program, whereas the control group did their traditional warm-up program. The ”PEP” program (”Prevent injury and Enhance Performance”) is an exercise program aiming to reduce injuries through neuromuscular and proprioceptive training including warm-up, flexibility training, strength exercises, plyometrics, and agility exercises. During the first season, there was an 88% reduction of ACL injuries in the intervention group compared with the control group. In the second season, the reduction of ACL injuries was 74%. The results of this study need to be evaluated with caution because the participants in the intervention groups were self-selected, which may result in bias. Aiming to rectify the weaknesses of the first study, Gilchrist et al. (2008) conducted a cluster-randomized controlled trial of the ”PEP” program. Almost 1500 college players were randomized to either an intervention group or a control group and followed prospectively for 12 weeks. However, the results were ambiguous. Although several of the secondary outcome measures approached significance, the reduction of the main outcomes (knee injuries, ACL injuries) was insignificant. Thus, the authors suggested that their study may have been underpowered due to a limited sample size or number of exposures. The results from these two studies are complemented by data from Pollard et al. (2006), who studied the in-season influence of the same program on lower extremity kinematics during landing in female players. The authors found that the program significantly reduced hip internal rotation and increased hip abduction. It was concluded that football practice combined with injury prevention training is effective in altering lower extremity motions that may play a role in predisposing female players to severe knee injuries such as ACL injuries.

Pfeiffer et al. (2006) used a prospective cohort design to assess the influence of a plyometric-based exercise program on ACL injury rates in 189 of 433 high-school female football players. The players were divided by clusters (schools) into intervention and control groups, and monitored for two consecutive seasons. The intervention consisted of plyometric training, agility drills, and exercises aiming to improve dynamic stabilization. Throughout the study period there was one ACL injury in the control group, compared with none in the intervention group. Clearly, this non-randomized study was underpowered to examine the effect of the program on the rate of non-contact ACL injuries.

Adopting a prospective crossover design, Kraemer & Knobloch et al. (2009) monitored 24 elite female football players from 2003 to 2006 to study the effect of proprioceptive training on the risk of hamstring muscle injuries and patellar and Achilles tendinopathy. The first half of the 2003/2004 season was defined as the control period, whereas the intervention period with a football-specific balance training protocol began with the second half of season 2003/2004 and ended in 2006. The authors reported a reduction of non-contact hamstring injuries by 63%, as well as reductions of patellar and Achilles tendinopathy. However, in addition to the non-randomized design, this crossover study is limited by the short collection period of control data. Thus, the evidence level is low.

The latest data on injury prevention in female football was provided by Kiani et al. (2010), who followed a cohort of 1506 13- to 19-year olds prospectively over one season. The cohort was divided into two groups; an intervention group and a control group. Throughout the season, the players in the intervention group used a warm-up and physical conditioning program consisting of balance, strength, and core stability exercises, with the aim of achieving an improved motion pattern that produces less strain on the knee joint. Compared with the control group, the players in the intervention group experienced a 77% and 90% reduction of knee injuries and non-contact knee injuries, respectively. Furthermore, the authors reported high compliance in the intervention group. However, the study used a non-randomized design and recorded exposure and compliance only among teams, not players. These are limitations that may cause biased results.

In a large cluster-randomized controlled intervention study over one season, Steffen et al. (2008c) tested the effect of the "F-MARC 11" injury prevention program on 2020 adolescent female football players. The teams randomized to the intervention group were asked to use exercises for core stability, lower extremity strength, neuromuscular control, and agility in every training session throughout the 8-month season. The results showed that the exercise program had no effect on the incidence of injuries. However, the training session log documented that the compliance of the intervention teams was low (52%), which indicates that the program can be difficult to implement successfully in youth football. Nonetheless, a per-protocol analysis revealed that the teams that had high compliance with the program did not incur fewer injuries than the teams that did not comply.

The experiences from this study led us to develop an exercise program to improve both the preventive effect of the program and the compliance of coaches and players. The revised program ("The11+") included key exercises and additional exercises to provide variation and progression. It was also expanded with a new set of structured running exercises that made it better suited as a comprehensive warm-up program for training and matches. The effectiveness of "The 11+" program was tested in our cluster-randomized controlled trial presented in Paper I.

In summary, there are promising indications that injuries in football can be prevented. In particular, there seems to be evidence that neuromuscular training programs, i.e. combinations of balance, strength, and plyometric exercises, as well as improvement of movement technique (running and cutting), can prevent injuries in female football. Data from female football is supported by data from male cohorts and risk factor studies. However, there is a need for studies with sound methodological designs to confirm that injuries can be prevented through training.

Compliance with the intervention

The effectiveness of an injury prevention program depends, among other things, on uptake of the intervention among participants, i.e. compliance. Hence, to better prevent injuries, it is crucial to understand the factors that influence athletes, coaches, and sports administrators to accept, adopt, and comply with the elements of the intervention (Finch, 2006; Finch & Donaldson, 2010).

However, documentation of participant compliance is often incomplete in studies examining the effectiveness of injury prevention protocols in team sports. Whereas a number of studies have neglected compliance altogether (Ekstrand et al., 1983a; Tropp et al., 1985; Surve et al., 1994; Lehnhard et al., 1996; Sharpe et al., 1997; Heidt et al., 2000; Junge et al., 2002; Árnason et al., 2005; Johnson et al., 2005; Scase et al., 2006; Mohammadi, 2007; Croisier et al., 2008; Delaney et al., 2008; Hölmich et al., 2009), some have noted the importance of compliance, but not reported it (Caraffa et al., 1996; Wedderkopp et al., 2003; Verhagen et al., 2004; Emery et al., 2005a; Mandelbaum et al., 2005; Árnason et al., 2008). Others have reported compliance, but not linked it to an injury prevention effect estimate (Hewett et al., 1999; Askling et al., 2003; Olsen et al., 2005; McGuine & Keene, 2006; Pfeiffer et al., 2006; Emery et al., 2007; Hägglund et al., 2007; Fredberg et al., 2008; Gilchrist et al., 2008). Finally, there are studies that have linked compliance to an effectiveness estimate (Söderman et al., 2000; Myklebust et al., 2003; Gabbe et al., 2006; Engebretsen et al., 2008; Steffen et al., 2008c; Kraemer & Knobloch, 2009; Kiani et al., 2010). Thus, we have limited data on the relationship between compliance and effectiveness.

Furthermore, some of studies in football that reports compliance are restricted by recording exposure to the intervention only on the team level (Gilchrist et al., 2008; Steffen et al., 2008c; Kiani et al., 2010). This provides us with information about the motivation, choices, and actions of the head coach. Recording individual participation, on the other hand, reveals the actual usage of the intervention for each player (Hewett et al., 1999; Söderman et al., 2000; Askling et al., 2003; Hägglund et al., 2007; Engebretsen et al., 2008). Therefore, recording team and player compliance together will provide detailed data on the overall compliance with the intervention (Figure 6).

In any case, when designing injury prevention approaches attention must be given to the determinants and influences of sports safety behaviors. To prevent injuries, sports injury prevention measures need to be acceptable, adopted and complied with by the athletes and sports bodies they are targeted at (Finch, 2006). If the athletes, coaches or sports administrators we are trying to work with will not use or adopt any of the prevention measures that we advocate, then all of our preventive efforts will fail, even though they might work in a research setting. To successfully implement sport safety policies in the sports community the prevention measures need not only prevent injuries, but also be acceptable to their participants, not change the essential nature or appeal of the sport, and not adversely affect participation or performance (Finch, 2006).

Regarding the latter, there are in fact indications that the effects of injury prevention training and performance enhancement can be synergistic in football players. For instance, several physiological characteristics such as plyometric power, muscle and core strength, speed, agility and balance are significant for successful performance in football (Stølen et al., 2005). Specific risk factor exploration and multi-faceted injury prevention approaches provide us with evidence that training of such characteristics not only enhances the performance, but also provides additive effects of reducing biomechanical risk factors (Paterno et al., 2004; Myer et al., 2005; 2006; Chappell & Limpisvasti, 2008), and thus have the potential to reduce the risk of injury. However, it has not been clearly demonstrated that injury prevention and performance enhancement can be reached through a single neuromuscular training protocol (Steffen et al., 2008a). Without the performance enhancement training effects coaches and players may not be motivated to participate in neuromuscular training. If such a synergistic program design were widely available, prevention oriented training could be instituted on a widespread basis with highly motivated players and coaches.

Table 6. Injury prevention studies in **female** *and* **male** *football players.*

Reference, Country, year, follow-up	Sample	Design, Level of evidence	Primary outcome	Intervention	Effect of intervention	Reported compliance
Female players						
Sharpe et al. (1997) USA, 1988-1992, 4 years	n=38 Amateur, aged 19.1 years	Retrospective cohort study [IV]	Recurrent ankle sprains	Either 1) a canvas, laced ankle brace, 2) taping, 3) a combination of taping and ankle bracing	Significantly fewer recurrences in the braced group.	n/a
Hewett et al. (1999) USA, n/a, 1 season	n=290; intervention: 97, control: 193 Youth, aged 14-18 years	Prospective cohort study [II]	Severe knee injuries (ACL, MCL)	Neuromuscular training program: plyometrics, flexibility, strength training 60-90 min, 3 times pr week, 6 weeks	Trend towards reduction of knee injuries in the intervention group	Individual compliance: 70% of the players completed all sessions
Heidt et al. (2000) USA, n/a, 1 year	n=300; intervention: 42, control: 258 Youth, aged 14-18 years	Randomized controlled trial [II]	Injuries overall	Cardiovascular, plyometric, coordination, strength, and flexibility training n/a min, 1-2 times pr week, 7 weeks	Significant reduction of the primary outcome in the intervention group	n/a
Söderman et al. (2000) Sweden, 1998, 1 season	n=221; intervention: 121, control: 100 Amateur, aged 20±5 years	Randomized controlled trial [II]	Acute lower extremity injuries	Home balance board training. 10-15 min, 7 times pr week in the pre-season, 3 times pr week in the competitive season	No reduction of the primary outcome. Higher risk of severe injuries in intervention group	Individual compliance: No difference in injury risk between high (>70 sessions) and low (35-69 sessions) compliance
Mandelbaum et al. (2005) USA, 2000-2001, 2 seasons	n=2946; intervention: 1041, control: 1905. Youth, aged 14-18 years	Prospective cohort study [II]	ACL injuries	Warm-up, flexibility, plyometrics, strength training, football-specific agility drills 20 min, every training session	74%-88% fewer ACL injuries in the intervention group	n/a
Pfeiffer et al. (2006) USA, n/a, 2 seasons	n=433; intervention: 189, control: 244 Youth, aged 14-18 years	Prospective cohort study [II]	Non-contact ACL injuries	Plyometric training, agility drills, dynamic stabilization 20 min	No reduction of the primary outcome	Individual compliance: mean 23 sessions
Gilchrist et al. (2008) USA, 2002, 12 weeks	n=1435; intervention: 583 control: 852 Youth, aged 19.8 years	Cluster-randomized control. trial [I]	Knee injuries	Warm-up, flexibility, plyometrics, strength training, football-specific agility drills 20 min, 3 times pr week	No reduction of the primary outcome. Trends towards reduction of knee injuries	Team compliance: 26±6 sessions
Steffen et al. (2008c) Norway, 2005, 1 season	n=2100; intervention: 1100, control: 1000. Youth, aged 13-17 years	Cluster-randomized control. trial [I]	Injuries overall	Core stability, balance, dyn. stabilization, eccentric hamstrings strength. 20 min, the first 15 pre-season sessions, 1 time pr week in the competitive season	No reduction of the injury outcomes	Team compliance: 23±9 sessions (52%). No difference in injury risk between teams with high and low compliance, and the control group
Kraemer & Knobloch (2009) Germany, 2003-2006, 3 seasons	n=24 Elite, aged 21±4 years	Prospective crossover study [IV]	Hamstring injuries & tendinopathy	Proprioception, balance, coordination, and plyometric training. Weekly basis.	Significant reduction of hamstring strain, patellar tendon, Achilles tendon, muscle, and knee strain injuries	Team compliance: 720-1080 minutes of intervention training each season. Dose-response relationship between intervention training time and injury rate
Kiani et al. (2010) Sweden, 2007, 1 season	n=1506; intervention: 777, control: 729 Youth, aged 13-19 years	Prospective cohort study [II]	Acute knee injuries	Warm-up, muscle activation, balance, strength, and core stability 25 min, 2 times pr week in the pre-season, 1 time pr week in the competitive season	77% reduction of knee injuries 90% reduction of non-contact knee injuries	Team compliance: 45 teams (94%) reported >75% compliance. 83% and 89% reduction of overall and non-contact knee injuries in high-compliant teams (vs. control group)

Table 6. Continued.

Reference **Country, year, follow-up**	**Sample**	**Design, Level of evidence**	**Primary outcome**	**Intervention**	**Effect of intervention**	**Reported compliance**
Male and female players						
Johnson et al. (2005) Sweden, n/a, 6 months	n=32; intervention: 16, control: 16 Elite, aged 20.1 years (♀), 22.9 years (♂)	Randomized controlled trial [II]	Injuries overall	Cognitive-behavioral training with relaxation and imagery training	83% reduction of injuries overall in the intervention group	n/a
Delaney et al. (2008) Canada, 2006, 3 months	n=278 Youth, aged 12-17 years	Cross-sectional study [IV]	Concussions, head injuries	Protective headgear	62% and 46% reduction of concussions and soft tissue head injuries	n/a
Male players						
Ekstrand et al. (1983a) Sweden, n/a, 6 months	n=180, intervention: n/a, control: n/a Amateur, aged 17-37 years	Randomized controlled trial [II]	Injuries overall	Warm-up, flexibility, cool-down 20 min, every training session	75% reduction of injuries in the intervention group	n/a
Tropp et al. (1985) Sweden, n/a, 6 months	n=439; intervention: n/a, control: n/a Amateur, age n/a	Randomized controlled trial [II]	Ankle sprains	Either 1) ankle orthosis, or 2) balance training 10 min, 5 times pr week for 10 weeks; 5 min, 3 times pr week in the competitive season	No reduction of injuries in previously uninjured players. 71%-82% reduction of injuries in players with previous ankle sprains	n/a
Surve et al. (1994) South Africa, n/a, 1 season	n=504; intervention: 244, control: 260 Elite & amateur, age n/a	Randomized controlled trial [I]	Ankle sprains	Semi-rigid ankle orthosis	No reduction of injuries in previously uninjured players. 60% reduction of injuries in intervention players with previous ankle sprains	n/a
Caraffa et al. (1996) Italy, n/a, 3 seasons	n=600; intervention: 300, control: 300 Elite & amateur, age n/a	Prospective cohort study [IV]	ACL injuries	Proprioceptive balance training 20 min, every day in the pre-season, 3 times pr week in the competitive season	87% reduction of ACL injuries in the intervention group	n/a
Lehnhard et al. (1996) USA, n/a, 4 seasons	n=1 team Amateur, age n/a	Prospective cohort study [IV]	Injuries overall	Progressive strength training (bench press, back squat) 2 times pr week	47% reduction of injuries after intervention	n/a
Junge et al. (2002) Switzerland, 1999-2000, 2 seasons	n=194; intervention: 101, control: 93 Youth, aged 14-19 years	Prospective cohort study [II]	Injuries overall	Warm-up, cool-down, taping of unstable ankles, adequate rehabilitation, balance exercises, flexibility, strength training Frequency: n/a	No reduction of the primary outcome Reduction of mild-, overuse-, non-contact-, training-, and groin injuries	n/a
Askling et al. (2003) Sweden, n/a, 11 months	n=30; intervention: 15, control: 15 Elite, aged 24/26 years	Randomized controlled trial [II]	Hamstring strains	Concentric and eccentric hamstring strength training. Every fifth day for 4 weeks, thereafter every fourth day for 6 weeks	Significant reduction of injuries in the intervention group (3/15) compared with the control group (10/15) ($p<0.05$)	Individual compliance: 100%

Table 6. Continued.

Reference **Country, year, follow-up**	**Sample**	**Design, Level of evidence**	**Primary outcome**	**Intervention**	**Effect of intervention**	**Reported compliance**
Male players						
Árnason et al. (2005) Iceland, 2000, 1 season	n=271; intervention: 127, control: 144 Elite, age n/a	Randomized controlled trial [I]	Acute injuries	Educational video-based awareness program. 2-hour workshop, prior to start of competitive season	No reduction of the injury outcomes in the intervention group	n/a
Hägglund et al. (2007) Sweden, 2003, 1 season	n=582; intervention: 282, control: 300 Amateur: aged 15-46 years	Cluster-randomized controlled trial [I]	Recurrent injuries overall	10-step progressive rehabilitation program after injury	66%-75% reduction of injuries in the intervention group	Individual compliance: 68%
Mohammadi et al. (2007) Iran, n/a, 1 season	n=80, intervention: 60, control: 20 Elite: aged 25±23 years	Randomized controlled trial [I]	Recurrent ankle sprains	Either 1) proprioceptive training, 2) strength training, or 3) orthosis	87% reduction of recurrent ankle sprains after proprioceptive training	n/a
Árnason et al. (2008) Iceland/Norway, 2001-2002, 2 seasons	n=n/a; intervention: n/a, control: n/a Elite, age n/a	Prospective cohort study [II]	Hamstring strains	Warm-up, stretching, flexibility, and/or eccentric hamstring strength training. 3 times pr week in the pre-season, 1-2 times pr week in the competitive season	35% reduction of hamstring strains by combining eccentric training with flexibility compared with only using flexibility exercises.	n/a
Croisier et al. (2008) Belgia, Brazil, France, 2000-2005, 9 months	n=462; intervention: 216, control: 246 Elite, aged 26±6 years	Prospective cohort study [II]	Hamstring injuries	Concentric and eccentric manual, isotonic, or isokinetic hamstring strength training Duration: n/a	Normalized injury risk for players previously increased risk after restoring a normal strength profile	n/a
Engebretsen et al. (2008) Norway, 2004, 1 season	n=508; intervention: 193, control: 315 Elite & amateur, age n/a	Randomized controlled trial [I]	Ankle, knee, groin, hamstring injuries	Neuromuscular, proprioceptive, and strength training. 3 times pr week for 10 weeks, 1 time pr week in the competitive season	No reduction of the injury outcomes in the intervention group	Individual compliance: 19%-29%. Per-protocol analysis: no effect
Fredberg et al. (2008) Denmark, 2002, 12 months	n=209; intervention: 5 teams, control: 7 teams Elite, aged 25 [18-38] years	Randomized controlled trial [I]	Achilles and patellar tendinopathy	Eccentric training and stretching of both Achilles and patellar tendons. 12 min, 3 times pr week	No reduction of the injury outcomes in the intervention group	Individual compliance: intervention completed 2.25 times pr week.
Hölmich et al. (2009) Denmark, 1997-1998, 1 season	n=977; intervention: 524, control: 453 Amateur, aged 24 years	Cluster-randomized controlled trial [I]	Groin injuries	Concentric and eccentric strength training, coordination and core stability exercises 13 min, every training session	No reduction of the injury outcome in the intervention group	n/a

Aims of the thesis

The aims of this thesis were:

1. To examine the effect of The 11+ injury prevention program on lower extremity injury rate in youth female football (Paper I)

2. To characterize the compliance of youth teams and players using The 11+ injury prevention program and to examine whether high compliance correlated with lower injury risk (Paper II)

3. To identify coaches' attitudes towards injury prevention training and to examine whether their attitudes were associated with the compliance or the risk of injury within their teams (Paper II)

4. To investigate whether there are any associations between technical, tactical, and physiological skill attributes in football and risk of injury in young female players (Paper III)

5. To investigate the risk of acute injuries on third generation artificial turf compared with grass in youth tournament football (Paper IV).

Methods

The aims of the four papers constituting this thesis required different designs and samples. All the subjects were sampled from Norwegian youth football. In Papers I-III we followed female youth players in the 2007 season, whereas we in Paper IV monitored female and male youth players in the Norway Cup-tournament from 2005 to 2008.

Design, participants & intervention

Intervention study (Paper I)

All of the 181 clubs in the 15- and 16-year divisions from the south, east and middle of Norway, organized by the regional districts of the Norwegian Football Association, received an invitation to participate in the study during one eight-month season (March to October 2007). To be included in the study, clubs had to carry out at least two training sessions per week, in addition to match play. The clubs practiced two to five times per week and played between 15 and 30 matches during the season. All clubs were recruited January through February 2007. Club enrolment registries for the 2007 league system were obtained from the regional districts of the Norwegian Football Association, and phone calls were made to the coaches, informing them about the purpose and the design of the study. After oral consent, a letter containing a more thorough description of the study and a study enrolment return form was sent out to the coaches, who also informed the players. Player participation was voluntary and individual written consent was signed by both players and parents.

One hundred twenty five clubs agreed to participate in the study, and they were randomized to the intervention group or control group (Figure 4). To minimize contamination bias within clubs, we utilized a cluster-randomized design.

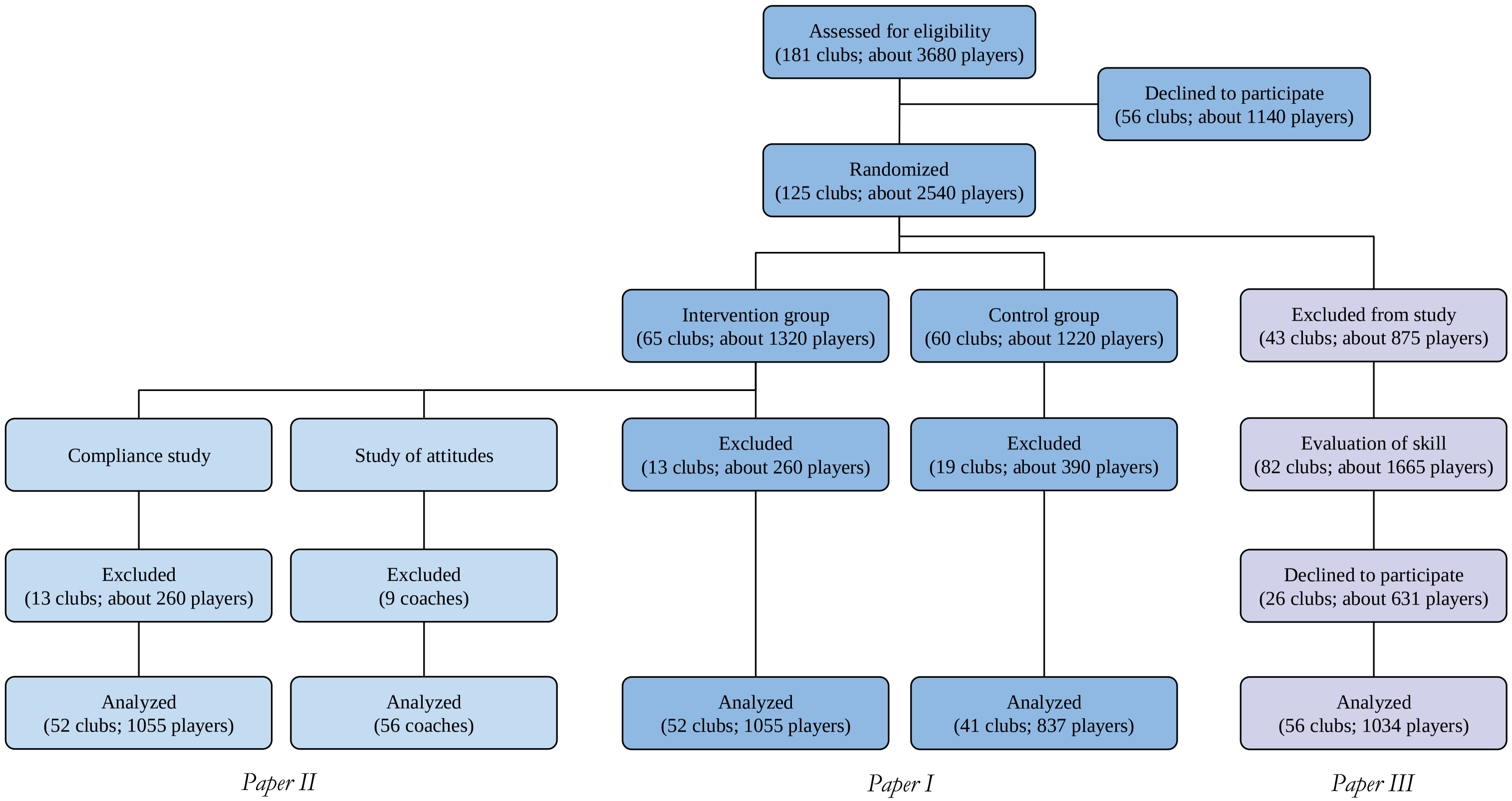

Figure 4. Flow of clusters (clubs) and players throughout the studies presented in Paper I-III.

The warm-up program, "The 11+", was developed by an expert group convened by FIFA, with representatives from the Oslo Sports Trauma Research Center, the Santa Monica Orthopaedic and Sports Medicine Research Foundation and the FIFA Medical Assessment and Research Centre, and its application was tested in one club before the start of the study. The program consisted of three parts (Table 7). The initial part was running exercises at slow speed combined with active stretching and controlled partner contacts. The running course included six to ten pairs of cones (depending on the number of players) approximately five to six meters apart (length and width). The second part consisted of six different sets of exercises; these included strength, balance and jumping exercises, each with three levels of increasing difficulty. The final part was speed running combined with planting and cutting movements.

Table 7. The 11+ warm-up exercise program used to prevent injury.

Exercise	Repetitions
I. Running exercises, 8 minutes (Opening warm-up, in pairs. The course consisted of 6 to 10 pairs of parallel cones)	
• Running, straight ahead	2
• Running, hip out	2
• Running, hip in	2
• Running, circling	2
• Running and jumping	2
• Running, quick run	2
II. Strength - Plyometrics - Balance, 10 minutes (one of three exercise progression levels each training session)	
• The plank	
Level 1: Both legs	3 x 20-30 s
Level 2: Alternate legs	3 x 20-30 s
Level 3: One leg lift	3 x 20-30 s
• Side plank	
Level 1: Static	3 x 20-30 s (each side)
Level 2: Dynamic	3 x 20-30 s (each side)
Level 3: With leg lift	3 x 20-30 s (each side)
• Hamstring	
Level 1: Nordic Hamstring Lower	3-5 reps
Level 2: Nordic Hamstring Lower	7-10 reps
Level 3: Nordic Hamstring Lower	12-15 reps
• Single-leg balance	
Level 1: Hold the ball	2 x 30 s (each leg)
Level 2: Throwing ball with partner	2 x 30 s (each leg)
Level 3: Test your partner	2 x 30 s (each leg)
• Squats	
Level 1: With toe raise	2 x 30 s
Level 2: Walking lunges	2 x 30 s
Level 3: One-leg squats	2 x 10 (each leg)
• Jumping	
Level 1: Vertical jumps	2 x 30 s
Level 2: Lateral jumps	2 x 30 s
Level 3: Box jumps	2 x 30 s
III. Running exercises, 2 minutes (final warm-up)	
• Running over the pitch	2
• Bounding run	2
• Running & cutting	2

In the beginning of the pre-season, February to mid-April 2007, we invited the coaches and team captains from all clubs in the intervention group to a three-hour workshop where the warm-up program was introduced. Courses were arranged at different locations in each of the eight regional districts by instructors from the Oslo Sports Trauma Research Center. The instructors had been familiarized with the 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 coaches and team captains.

The coaches received an instructional DVD demonstrating all of the exercises in the program, an attractive loose-leaf exercise book and small exercise cards attached to a neck hang. In addition, the coaches and every player received a poster explaining every exercise. The information material detailed each exercise and explained the proper form for each, as well as common biomechanical mistakes. It also described the principles of progression in the exercise prescription. We asked the coaches to use the complete exercise program as the warm-up for every training session throughout the season, and to use the running exercises in the program as part of their warm-up for every match.

When introducing the program to the clubs, our main focus was to improve awareness and neuromuscular control during standing, running, planting, cutting, jumping, and landing. We encouraged the players to concentrate on the quality of their movements and put emphasis on core stability, hip control, and proper knee alignment during both static and dynamic movements (Figure 5). We asked the coaches and players to watch each other closely and give each other feedback during training. Once players were familiar with the exercises, the program could be completed in about 20 minutes.

Study of compliance and attitudes (Paper II)

The 65 of the 125 clubs allocated to the intervention group in the randomized controlled trial (Paper I) formed the basis for Paper II (Figure 4). The recording of compliance included all the clubs (n=65) in the intervention group, and the recording of attitudes and beliefs towards injury prevention included all the coaches (n=65) of the intervention clubs.

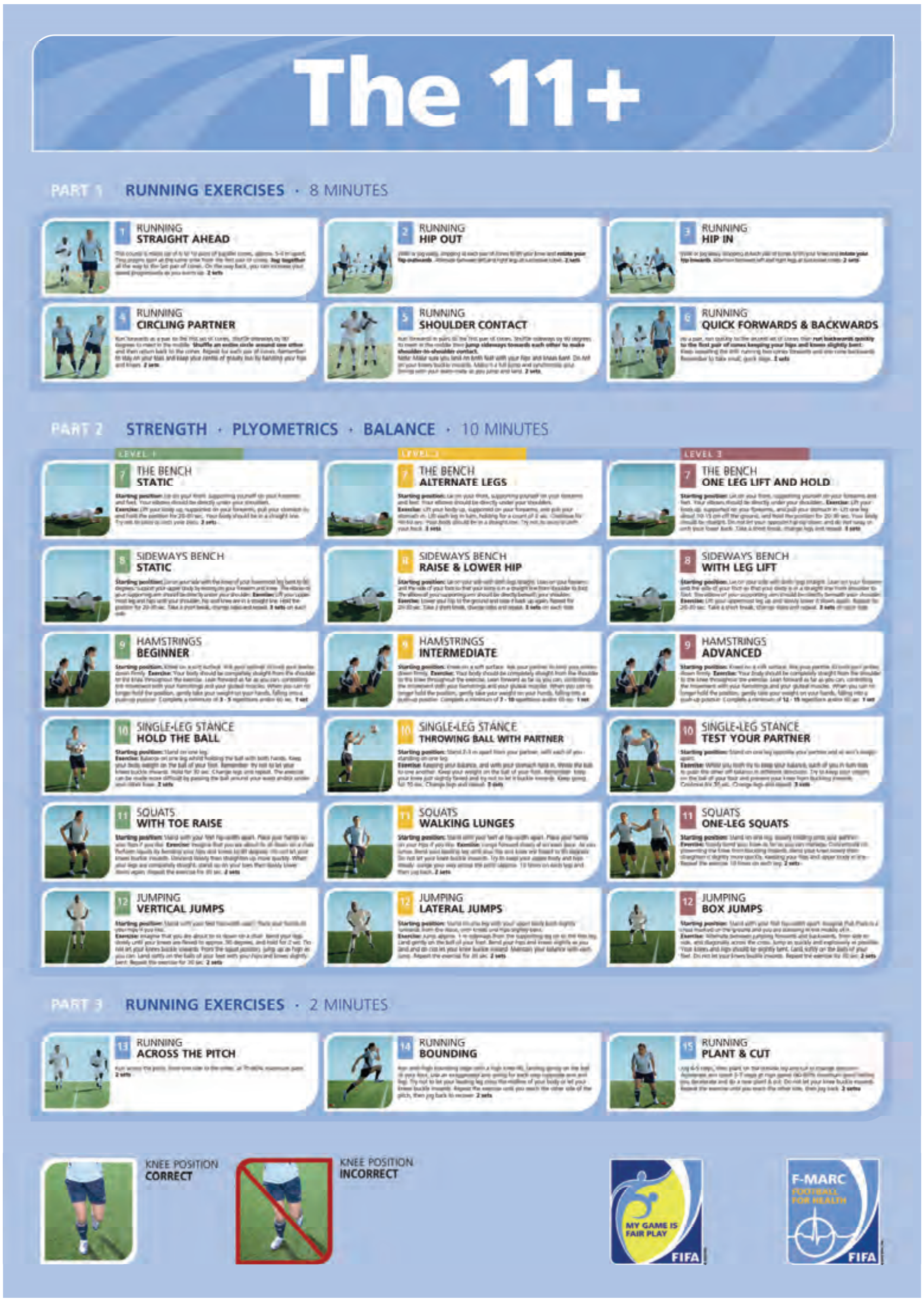

Figure 5. Poster detailing all the exercises in the 11+ warm-up exercise program used to prevent injury.

Skill level and risk of injury (Paper III)

This study was based on data from the randomized controlled trial conducted in Paper I. To be included in the study clubs were required to have recorded injuries and exposure for the complete 2007-season. Altogether, 82 of the 125 clubs entering the randomized controlled trial fulfilled the inclusion criterion and formed the basis for Paper III (Figure 4). This investigation included a prospective registration of the incidence of injuries, and a retrospective evaluation of the skill level of players.

Turf type and risk of injury in Norway Cup (Paper IV)

Using a prospective cohort design, data was collected from 2005 to 2008 in the Norway Cup, which since its start in 1972 has become one of the largest international youth football tournaments. It is arranged in Oslo in the first week of August every year, with more than 1 500 teams and 17 000 players participating. The matches are played from 8 AM until 8 PM for six consecutive days in large recreational areas with more than 40 playing fields.

Five of the fields were covered with third-generation artificial turf. All 11-a-side classes were included, corresponding to boys and girls 13 to 19 years of age. The play-off matches and 7-a-side matches were excluded because they were played on natural grass only. Over the four tournaments the study comprised more than 4 000 teams and 60 000 players; approximately one third of these were girls.

Data collection methods

Injuries and exposure (Papers I-III)

We defined the primary outcome as an injury to the lower extremity. Secondary outcomes were defined as any injury, or an injury to the ankle, knee, or other body parts.

The coaches reported injuries and individual exposure for each training session and match on weekly registration forms (appendix 1) throughout the study period. These were submitted by e-mail, mail, or fax to the Oslo Sports Trauma Research Center. Data on players who dropped out during the study period were included for the entire period of their participation.

One physical therapist and one medical student who were blinded to group allocation staffed a call centre at the Oslo Sports Trauma Research Center. These injury recorders were given specific training on the protocols for injury classification and injury definitions (Table 8) before the start of the injury recording period. These are in accordance with the consensus statement on injury definitions and data collection procedures (Fuller et al., 2006). Every player who was reported to be injured by their coach was called to assess aspects of the injury based on a standardized (Olsen et al., 2006) injury questionnaire (appendix 2) and the players were in most cases reached within four weeks (range: one day to five months) after the injury had occurred.

Table 8. Operational definitions used in the recording of injury.

Exercise	**Repetitions**
Reportable injury	An injury occurred during a scheduled match or training session, causing the player to be unable to fully take part in the next match or training session.
Player	A player was entered into the study if she was registered by the coach on the club roster as participating for the club's team competing in the 15- or 16-year divisions.
Return to participation	The player was defined as injured until she was fully fit to take part in all types of training and matches.
Type of injury	Acute – injury with sudden onset associated with known trauma. Overuse – injury with gradual onset without known trauma. Contact – injury resulting from contact with another player. Non-contact – injury occurring without contact with another player. Re-injury – injury of the same type location sustained previously in the career.
Severity[1]	Minimal injuries – absence from match and training for 1 to 3 days. Mild injuries – absence from match and training for 4 to 7 days. Moderate injuries – absence from match and training for 8 to 28 days. Severe injuries – absence from match and training for more than 28 days.
Exposure	Match exposure – hours of matches. Training exposure – hours of training.

[1]In almost all cases, players sustaining moderate or severe injuries were examined by a doctor. If there was any doubt about the diagnosis the player was referred to a sports medicine centre for follow up, which often included imaging studies or arthroscopic examination. In cases of minimal or mild injuries, the players were examined by a local physiotherapist, the coach, or not at all. None of the injured players were examined or treated by any of the authors or injury recorders involved in the study, and we had no influence on the time it took a player to return to club activities.

Compliance (Paper II)

The coaches recorded the individual player participation in the intervention, as the number of minutes of exposure, for each training session and match on the weekly registration forms (appendix 1). Furthermore, for each session the coaches quantitatively recorded whether the warm-up program was carried out, as well as the participation of each player in the program (yes/no). For comparison with results from previous studies compliance was defined and reported in multiple ways (Figure 6).

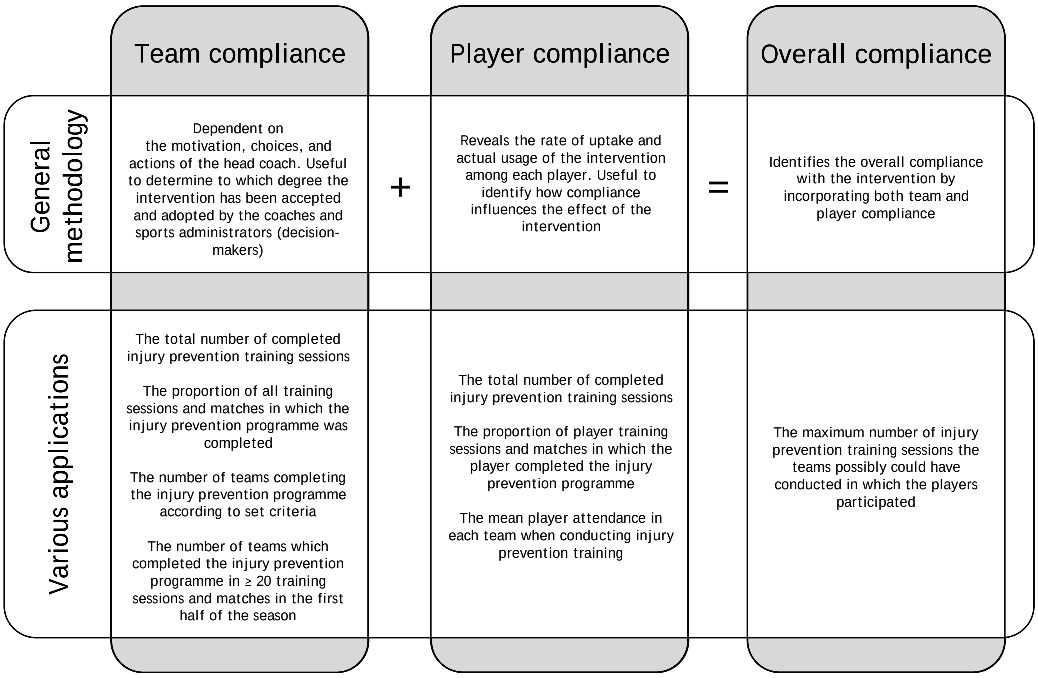

Figure 6. The distinction between compliance among teams and players, and definitions of compliance used in this study.

Attitudes towards injury prevention training (Paper II)

After the season, from mid-October through November, every coach in the intervention group was called to evaluate the complete warm-up program and the exercises used, as well as to assess attitudes and beliefs towards injury prevention training in general. This retrospective study was based on a questionnaire designed by the authors, consisting of 28 closed and three open questions (appendix 3). The questionnaire was standardized using dichotomous or 5-point Likert scale response alternatives in accordance with questionnaire design guidelines to ensure reliability and validity (DeVellis, 2003). All interviews were conducted by a physical therapist.

Football skills (Paper III)

A standardized questionnaire designed to assess the football skills of each individual player compared with the rest of the team (appendix 4) was mailed or e-mailed to the coach of each team two months after the end of the 2007 season. The coach completed one questionnaire for each player. The skill assessment included 12 technical, tactical, and physiological attributes. The technical attributes comprised ball receiving, passing and shooting (precision, power), heading (power and timing), dribbling, and tackling. The tactical attributes comprised decision-making when the player had ball possession, decision-making when the team, but not the player had ball possession (offensive decisions), and decision-making when the opposing team had ball possession (defensive decisions). The physiological attributes comprised endurance, speed/agility, strength (football-specific strength), and coordination/balance. The coach categorized each player into four quartiles; weakest, below average, above average, or best. This was done separately for each of the 12 skill attributes.

Injuries and exposure (Paper IV)

The injury recording in the Norway Cup involved the team coaches and the referees. Prior to each match the referee visited the referee department to receive two injury record forms as well as the score card. The referee handed out one injury record form to the coach of each team. The coaches were asked to fill in the form if any injuries occurred during the match. Immediately after the match the referee collected the injury forms and delivered them to the tournament transport unit, who delivered the score card and injury forms to the technical department, where the injury data were plotted into a database by trained personnel.

The team coaches and the referees were informed specifically about the purpose and methodology of the study before the start of the tournament. The referees were provided with a letter detailing the study when they checked in to the referee department. Also, the day before tournament start all the referees were gathered in a plenary meeting where we described the procedures for the injury registration. The referees were also followed up every day by study personnel in the referee department. Every team coach was informed about the study in a letter distributed to them one month before attending the tournament, as well as on arrival during check-in.

The injury record form (appendix 5) was a bilingual (Norwegian/English) check-box form. The form included instructions on how to record the information. The coaches recorded the location, type, severity and cause (acute/overuse; contact/non-contact) of injury. The referee completed the team names and the unique match ID, which allowed for subsequent data extraction of the age and gender of the players, as well as the playing field number and turf type (artificial turf or natural grass). No personal data was recorded in the injury forms or stored in the injury database, and informed consent was not obtained.

An injury was defined as any injury, painful condition or physical complaint sustained by a player in a Norway Cup match, irrespective of the need for medical attention or time loss from football activities (Fuller et al., 2006). Contact injuries were defined as injuries resulting from contact with another player, whereas non-contact injuries were defined as injuries occurring without contact with another player. Acute injuries were defined as injuries with a sudden onset, associated with a known trauma. Overuse injuries were defined as injuries with a gradual onset and no known trauma. Because overuse injuries have a gradual onset, they could not be attributed to a particular turf type, and hence, their injury incidence could not be compared between turf types. The injury recording method did not allow for any assessment of injury exacerbations or recurrences. Injuries were grouped into four categories of severity by the coaches according to the expected length of absence from matches and training sessions: minimal (1-3 days); mild (4-7 days); moderate (8-28 days); severe (>28 days). Match exposure was calculated on a team basis on the assumption that each match involved 11 players and lasted for 40, 50 or 60 minutes, according to the age class.

Statistical analysis

All statistical analyses were conducted in SPSS (SPSS for Windows 15.0, SPSS Inc, Chicago, Ill.) or STATA (STATA 10.0, Stata Corporation, Lakeway Drive, Texas, 2007).

Power calculation

In Paper I the sample size was based on injury incidence data from Norwegian youth female football during the 2005 season (Steffen et al., 2008c). From this study, we estimated that 16% of the players would suffer an injury to the lower extremities and about 10-12 % of the players would injure their knee or ankle during one season. Given an estimated inflation factor for cluster effects due to randomization by clubs of 1.8, 900 players in each group would provide an acceptable power of 0.86 at the 5% significant level to detect a 40% reduction in the number of players with a lower extremity injury. Our model was based on 18 players per club and a drop-out rate of 15%, which means that we needed to include approximately 120 clubs with 2150 players.

Statistical methods

Descriptive data are generally presented as means with standard errors or 95% confidence intervals; e.g. for risk exposure and injury rates (Papers I-IV), compliance with the warm-up program (Papers I & II), attitudes towards injury prevention training (Paper II), and skill level

(Paper III). Two tailed P values ≤ 0.05 were regarded as significant. The summary measure of injury incidence (*i*) was calculated in Papers I, II, and III according to the formula $i = n/e$, where n is the number of injuries during the study period and e the sum of exposure time expressed in player hours of match, training or in total. In Paper IV only match exposure was included.

In Paper I we used the rate ratio of the injury risk according to the intention-to-treat principle to compare the risk of an injury in the intervention and control groups. Cox regression was our analysis tool for the primary outcome as well as the secondary outcomes, and we used the robust calculation method of the variance-covariance matrix (Lin & Wei, 1989), taking the cluster randomization by clubs into account. Rate ratios were tested with Wald test. One way analysis of variance was used to estimate the intra-cluster correlation coefficient to obtain estimates of the inflation factor for comparison with planned sample size. We used the inverse of the difference between percentages of injured players in the two groups to calculate the number needed to prevent one injury. We used one minus survival plots based on the Cox regression to evaluate possible delays of the injury prevention effects of the program in the intervention group compared with the control group.

In Papers I and II we used a Poisson regression model based on generalized estimating equations taking cluster effects into account as a per protocol analysis to compare the rate ratios of risk of injury between teams as well as players (independent of club) stratified into tertiles of compliance according to the number of prevention sessions completed: low, intermediate, and high.

In Paper II we also used χ^2-tests to compare categorical variables between these subgroups and one-way analyses of variance (ANOVA) to compare continuous variables. To investigate the relation between the coaches' attitudes and compliance, and between attitudes and injury risk, logistic regression analyses were used.

In Paper III we used χ^2-tests to examine whether there were any relationships between the players' skill level across the 12 skill attributes. In each test the players were classified in terms of whether they were equally assessed in two skill attributes. Unpaired two-sample t-tests were used to compare the match participation of the players with high and low skill in each skill attribute. We used the Cox regression model from Paper I to estimate the relation between skill level and risk of injury. Interaction between group allocation (intervention or control) and skill level for each of the 12 attributes was tested with a z-test, using the results from the Cox regression model with injuries overall as the dependent variable. No significant interaction was found (all $p>0.20$) and the two groups were merged.

In Paper IV we used ordinal regression analyses with injuries as the dependent variable to estimate the risk of injury on artificial turf and grass. We used logistic regression analyses in subgroups where the number of injuries was limited. To adjust all estimates for potential confounders, tests of interaction between turf type, age, and gender were conducted by adding three-way and two-way cross-product terms, with step-wise removal of the cross-product terms if no interaction was found.

Research ethics

All studies were approved by the Regional Committee for Medical and Health Research Ethics. All participants received written and oral information about the study, and it was emphasized that participation was voluntary. Consent was signed by both players and parents when personal data was stored (Papers I-III). All collected data were treated confidentially.

Results and discussion

Injury prevention in youth female football (Paper I)

The final sample consisted of 52 clubs (1055 players) in the intervention group and 41 clubs (837 players) in the control group (Figure 4). The players in the two groups were similar in age (15.4 ± 0.7 (SD) years in both groups) and age distribution.

The exposure to football was 49 899 hours for the intervention group and 45 428 hours in the control group. During the eight month season, 301 (16%) of the 1892 players included in the study sustained a total of 376 injuries; 161 injuries in the intervention group, 215 injuries in the control group. The overall incidence of injuries was 3.9 ± 0.2 injuries per 1000 player hours (8.1 ± 0.5 injuries in matches, 1.9 ± 0.2 injuries in training).

Although the rate ratios for the different outcome variables indicated a consistent effect on injury risk across most injury types, the primary outcome – lower extremity injury – did not reach statistical significance when adjusted for the cluster sampling (rate ratio 0.71; 95% confidence interval 0.49 to 1.03, P=0.072). However, there was a significant reduction in several secondary outcome variables; the rate of severe injuries, overuse injuries, and injuries overall was reduced by 45%, 53%, and 32%, respectively (Table 9).

Table 9. Intention-to-treat analysis. Values are numbers (percentages) of injured players.

	Intervention group (n=1055)	Control group (n=837)	Intracluster correlation coefficient †	Inflation factor †	Number needed to treat	Rate ratio (95% CI)*	P value
All injuries	135 (13.0)	166 (19.8)	0.096	2.86	15	0.68 (0.48 to 0.98)	0.041
Match injuries	96 (9.1)	114 (13.6)	0.045	1.87	22	0.72 (0.52 to 1.00)	0.051
Training injuries	50 (4.7)	63 (7.5)	0.044	1.86	36	0.68 (0.41 to 1.11)	0.120
Lower extremity injuries	121 (11.5)	143 (17.1)	0.088	2.70	18	0.71 (0.49 to 1.03)	0.072
Knee injuries	33 (3.1)	47 (5.6)	0.028	1.54	40	0.62 (0.36 to 1.05)	0.079
Ankle injuries	45 (4.3)	49 (5.9)	0.026	1.50	63	0.81 (0.50 to 1.30)	0.378
Acute injuries	112 (10.6)	130 (15.5)	0.070	2.35	20	0.74 (0.51 to 1.08)	0.110
Overuse injuries	27 (2.6)	48 (5.7)	0.040	1.76	32	0.47 (0.26 to 0.85)	0.012
Severe injuries	45 (4.3)	72 (8.6)	0.028	1.54	23	0.55 (0.36 to 0.83)	0.005

*Cox model calculated according to method of Lin & Wei (1989) which takes cluster randomization into account
†GEE model with clubs as cluster unit

There were also significantly fewer players in the intervention group with two or more injuries than in the control group (rate ratio 0.51; 95% confidence interval 0.29 to 0.87), while a reduction in the risk of re-injuries did not reach statistical significance (rate ratio 0.46; 95% confidence interval 0.20 to 1.01).

The effect of various intervention programs designed to reduce the risk of injury to the lower extremities in female youth football has been studied previously (Hewett et al., 1999; Heidt et al., 2000; Söderman et al., 2000; Mandelbaum et al., 2005; Gilchrist et al., 2008; Steffen et al., 2008c; Kiani et al., 2010). However, these studies were either non-randomized, had small sample sizes, low compliance among the participants, or had other significant methodological limitations.

The tested program was developed on the basis of the "F-MARC 11" program (Dvorak & Junge, 2005) and the "PEP" program (Mandelbaum et al., 2005), combined with running activities at the start and the end (Olsen et al., 2005). The running exercises were chosen not just to make the program more suitable as a warm-up, but also to teach proper knee control and core stability during cutting and landing. Furthermore, the "11+" exercises include both variety and progression of difficulty. These elements were absent from the "F-MARC 11", the training program we tested in a previous randomized controlled trial (Steffen et al., 2008c), but existed in other successful prevention programs (Caraffa et al., 1996; Myklebust et al., 2003; Emery et al., 2005a; Olsen et al., 2005). The focus on core stability, balance, neuromuscular control, as well as hip control and knee alignment that avoids excessive knee valgus during both static and dynamic movements is a feature of earlier intervention studies (Caraffa et al., 1996; Hewett et al., 1999; Heidt et al., 2000; Myklebust et al., 2003; Mandelbaum et al., 2005; Olsen et al., 2005; Kiani et al., 2010). This rationale is justified by data from studies on the mechanisms of ACL injuries (Boden et al., 2000; Ebstrup & Bojsen-Møller, 2000; Olsen et al., 2004; Hewett et al., 2005; Krosshaug et al., 2007b). These studies indicate that players could benefit from not allowing the knee to sag medially during plant and cut movements, when suddenly changing speed, or when being perturbed by opponents. The program therefore focused on proper biomechanical technique and improvement of awareness and control during standing, running, planting, cutting, jumping, and landing.

A set of balance exercises was included in the program, and during single-leg balance training the players were also perturbed by a teammate; this provided an additional challenge to the ability to maintain a stable core and proper alignment. Studies from football (Caraffa et al., 1996; Mandelbaum et al., 2005; Kiani et al., 2010) suggest that the rate of ACL injuries can be reduced by improving dynamic and static balance, neuromuscular control, and proprioception. The prevention program we tested is multi-faceted and addresses many factors that could be related to the risk of injury (jogging and active stretching for general warm-up, strength, balance, awareness of vulnerable hip and knee positions, technique of planting, cutting, landing and running), and it is not possible to determine exactly which exercises or factors that may have been responsible for the observed effects. One of the strength exercises, "Nordic Hamstring Lowers", has previously been shown to increase eccentric hamstring muscle strength (Mjølsnes et al., 2004) and decrease the rate of hamstring strain injuries (Árnason et al., 2008). Some studies also suggest that the hamstrings can act as agonists to the anterior cruciate ligament during stop and jump tasks (Hewett et al., 1996; Chappell et al., 2002; Fagenbaum & Darling, 2003), at least at knee flexion angles above 30º (Beynnon et al., 1995; Li et al., 1999; Withrow et al., 2008). Hence, there is a possibility that stronger hamstring muscles can prevent injuries to the ligament, but this theory has never been tested directly. Based on data from volleyball (Hewett et al., 1996; Bahr et al., 1997) and team handball (Myklebust et al., 2003; Olsen et al., 2005) we also encouraged players to attenuate landings with increased hip and knee flexion, and to land on two legs, rather than one. In summary, further studies are needed to determine what the key components are, so that future programs might require less time and effort.

In terms of contraindications, no negative effects of the program were observed, except for a few coach reports on muscular soreness in the beginning of the intervention period and one report of a minor hamstring strain.

Compliance with the injury prevention program (Papers I and II)

The 52 teams completed the injury prevention program in 2279 (mean 44 ± 22 sessions, range 11-104) out of 2957 training sessions and matches throughout the season (77%), corresponding to 1.3 times per week. Of all the teams, 60% (n=31) completed the injury prevention program two times per week or more in accordance with the recommendation. In all tertiles of compliance, the majority of the injury prevention sessions were conducted in the first half of the season (March-June) (see Paper II for details).

The 1055 players completed the injury prevention program in 28 212 (mean 27 ± 19 sessions, range 0-95) out of 35 589 sessions throughout the season (79%), corresponding to 0.8 sessions per week. Furthermore, for each session the average number of players per team that participated in the injury prevention program was 12.0, corresponding to only 59% of all players on the roster (mean 20.3 per team). Since the team compliance was 77%, all the enrolled players therefore completed the injury prevention program in 47% of the maximum number of sessions the teams possibly could have conducted. Thus, the intervention players completed fewer injury prevention sessions than the recommendation of at least two sessions per week. Nonetheless, they still experienced a 30-50% reduction in the risk of various injuries compared with the controls. This indicates that the injury prevention program achieved the desired injury preventive effect.

In our previous intervention study we tested the effect of a training program, "The 11" (Dvorak & Junge, 2005), in a similar cohort of female youth football athletes (Steffen et al., 2008c). We were encouraged that the team compliance in this trial was high, much higher than with the previous program (77% vs. 52%). One key objective for the revision was to improve the compliance among coaches and players, and with this in mind, the revised program was expanded with more exercises to provide variation and progression. It also included a new set of structured running exercises to make it better suited as a stand-alone warm-up program for training and matches. In addition, the first part of the program included partner exercises, which seemed to appeal to the players.

It should be noted that the resources used to promote the program among the intervention teams were moderate; to the extent that it should be possible to replicate program implementation in large-scale nation-wide programs. The coaches and team captains were introduced to the program during one 3-hour training session. In addition, to boost compliance, we also developed new information material for coaches and players; a DVD showing all of the exercises, a poster, an attractive loose leaf exercise book, and small exercise cards attached to a handy neck hang which the coaches could bring to the training field. However, it was up to the coaches and team captains to teach the program to the rest of the players on the roster. Furthermore, the clubs received no follow-up visits throughout the season to refresh coaching skills or give players feedback on their performance. In spite of the moderate efforts to promote the program, compliance was good and we saw effects on the risk of injury in the clubs in the intervention group. This indicates that it should be possible to implement the program at the community level, by including injury prevention as part of basic coaching education and making educational material such as that developed for the current study available to teams, coaches, players and parents.

The technical nature of many of the exercises in the program required players to focus during training to gain the intended benefit. Site visits indicated that not all of the players appeared to concentrate fully on the performance of the exercises, which may be expected for this age group. Furthermore, the compliance logs documented that only a handful of clubs completed the requested minimum of two training sessions a week. However, we included all clubs and players in the intention-to-treat analysis, which means that the preventive effect of the program may be even higher than we have reported. This is supported by subgroup per-protocol analyses within the intervention group, demonstrating a lower injury risk among the most compliant players.

Level of compliance and risk of injury (Papers I & II)

The players with high compliance (mean 49 ± 14 sessions per season, 1.5 sessions per week; range 33 to 95 sessions per season) completed six times as many injury prevention sessions as the players with low compliance (mean 8 ± 5 sessions per season, 0.2 sessions per week; range 0 to 14 sessions) and twice as many as the players with intermediate compliance (mean 23 ± 5 sessions per season, 0.7 sessions per week; range 15 to 32 sessions per season).

There was no difference in the risk of injury between teams with high (mean 69 ± 15 sessions per season, 2.1 sessions per week; range 52 to 104 sessions per season), intermediate (mean 42 ± 6 sessions per season, 1.3 sessions per week; range 30 to 52 sessions per season), and low (mean 21 ± 6 sessions per season, 0.6 sessions per week; range 11 to 28 sessions per season) compliance, and the teams in the control group (Table 10). However, the risk of injury was 55% and 87% higher among players with intermediate compliance and players in the control group, respectively, compared with players with the highest compliance. In contrast, there was no significant difference (P=0.13) in injury risk between the players with the highest and lowest compliance.

Table 10. Per-protocol analysis. Injury risk among intervention teams and players stratified into high-, intermediate- and low compliance compared with teams and players in the control group.

	Teams			Players		
	Injury incidence	Rate ratio	P value	Injury incidence	Rate ratio	P value
All injuries						
High compliance	3.1 [2.5-3.8]	-	-	2.6 [2.0-3.2]	-	-
Intermediate compliance	3.7 [2.8-4.7]	1.19 [0.65-2.18]	0.56	4.0 [3.0-5.0]	1.55 [1.05-2.28]	0.024
Low compliance	2.7 [1.6-3.7]	0.80 [0.41-1.59]	0.53	3.7 [2.2-5.3]	1.49 [0.89-2.47]	0.13
Controls	4.7 [4.1-5.4]	1.51 [0.92-2.48]	0.10	4.7 [4.1-5.4]	1.87 [1.38-2.53]	0.001
Acute injuries						
High compliance	2.5 [1.9-3.1]	-	-	2.1 [1.6-2.6]	-	-
Intermediate compliance	3.4 [2.5-4.3]	1.36 [0.71-2.60]	0.35	3.5 [2.5-4.4]	1.64 [1.09-2.49]	0.018
Low compliance	2.3 [1.3-3.3]	0.87 [0.41-1.81]	0.71	3.3 [1.8-4.7]	1.58 [0.91-2.72]	0.10
Controls	3.5 [3.0-4.0]	1.45 [0.85-2.49]	0.18	3.5 [3.0-4.0]	1.71 [1.22-2.39]	0.002

High compliant tertile is reference group

Interestingly, the preventive effect of The 11+ therefore increased with the rate of use, at least when conducted more than 1.5 times per week on average. No studies have similarly compared the risk of injury in players and teams with high, intermediate, and low compliance with an intervention to prevent injuries. However, similar indications of exposure-response relationships have been found previously (Myklebust et al., 2003).

In contrast to the findings among players, we found no significant differences in the overall or acute risk of injuries between teams with different levels of compliance. This is explained by the large variations in compliance among the players within each team; the players with high compliance had a six fold higher use of the program compared with the players with low compliance. These findings emphasize the inadequacy of recording compliance on a team basis only. The overall compliance is a product of the compliance among the teams and the player participation rate (Figure 6).

It should be noted that the teams with low compliance reported three times lower exposure to football than the teams with high compliance, and four of ten teams with low compliance did not report any injuries at all. Even though calculations of injury incidence take exposure into account, a minimum exposure is necessary to be at risk of injury. Moreover, coaches less thorough in conducting the injury prevention program and recording compliance may have also been less likely to record injuries. If so, the injury incidence in the low compliance group may have been underestimated somewhat.

The program was designed to prevent injuries. However, to make it attractive for coaches and players, The 11+ was specifically tailored to football players and we included elements of variation and progression in the exercise prescription. We also focused on organizing streamlined and efficient three-hour educational meetings at baseline, where the coaches were provided with a selection of material detailing the exercises. Although we gave a set of footballs to the teams that completed the collection of injuries and exposure, no incentives were provided to ensure high compliance by coaches and players other than telephone and e-mail contacts related to data collection. Indeed, the compliance rates among teams in the current study was higher than previously reported among teams (Söderman et al., 2000; Myklebust et al., 2003; Olsen et al., 2005; Emery et al., 2007; Árnason et al., 2008; Steffen et al., 2008c), as well as among players (Gabbe et al., 2006; Pfeiffer et al., 2006; Engebretsen et al., 2008). In addition, our intervention period lasted longer than comparable interventions in other studies. Although compliance decreased from the first to the second half of the season (see Paper II for details), these findings may imply that a long-term intervention period is not synonymous with low motivation and compliance among the participants. Other factors, such as the content, the relevance, the availability, and the perceived difficulty of the intervention may also play an important role.

Attitudes towards injury prevention training (Paper II)

Compliance with an intervention depends upon the motivation among the participants to perform a certain safety behavior and that the barriers associated with the behavior are limited (Finch, 2006). Fifty-six coaches completed the study of attitudes and beliefs towards injury prevention training; 50 belonged to teams which completed the compliance study, while six belonged to teams that dropped out during the season (Figure 4).

The strongest motivator for the coach was the expectation of fewer injuries. All coaches (n=56) emphasized the importance of including injury prevention in the training (80% (n=45) stated that it is "very important", and 20% (n=11) that it is "important") and the majority believed that the risk of injury among their players was high (29% of the coaches, n=16) or intermediate (59%, n=33). Nonetheless, more than half of the coaches (54%, n=30) had never previously conducted injury prevention training; this suggests that previous barriers associated with such training were too high.

The 11+ was completed in 20 minutes once the players were familiar with the program. In addition to providing players with a solid warm-up, the program included exercises aimed at improving strength, core stability, plyometrics, and balance, components which presumably would be beneficial both in preventing injuries and enhancing performance. Nevertheless, time constraints were perceived as a barrier by many of the coaches; the probability of having low compliance with the injury prevention program was 87% higher if the coach believed that the program was too time-consuming (odds ratio 0.13; 95% confidence interval 0.03 to 0.60, P=0.009). Moreover, if the coach held the opinion that the program did not include enough football-specific activities, the probability of low compliance increased by 81% (odds ratio 0.19; 95% confidence interval 0.40 to 0.92, P=0.038). This indicates that content is important when implementing injury prevention measures in the sports community. The finding corresponds with theories proposing that when the barriers associated with a task are perceived as great, the task is less likely to be carried out (Ajzen & Fishbein, 1980; Bandura, 1997).

The vast majority of all coaches (95%, n=53) believed that their attitudes towards injury prevention training influenced their players' motivation to perform the program – they served as role models. Furthermore, 75% (n=42) of the coaches responded that the media and high-profile athletes influence the motivation to carry out injury prevention training. These findings are supported by well-founded theories suggesting that if people think their significant others want them to perform a behavior, this results in a higher motivation and greater likelihood of action (Ajzen & Fishbein, 1980; Rivis et al., 2006).

There was no significant relationship between the injury risk of the teams and the overall attitude towards injury prevention training among their coaches (p=0.33). However, injuries were half as likely in the teams of the coaches who previously in their coaching career had undertaken injury prevention training compared with teams of coaches who had not used such training (odds ratio 0.54; 95% confidence interval 0.33 to 0.87, P=0.011). Previous experience with injury prevention training seems to improve the positive attitudes of coaches and may increase the implementation of The 11+ in both training sessions and before matches.

Methodological considerations (Papers I & II)

The randomized controlled trial took place in the 15-and-16 year divisions from the south, east, and middle of Norway and recruited 69% of all clubs and players organized by the Norwegian Football Association in these areas. Of the 181 clubs assessed for eligibility, 56 declined to participate and 125 were randomized. During the recruitment of clubs, the most common barrier to participation that coaches reported was the additional work of recording and reporting data weekly. Our study of attitudes also demonstrated that other common barriers were related to the duration and content of the intervention. Thus, although we recruited a high proportion of eligible teams, the final sample probably included teams with more dedicated coaches. After inclusion, we had to exclude 13 intervention clubs and 19 control clubs because they did not deliver any data on injury or exposure. In most cases the coaches were volunteers, such as parents, and the most common reason for not reporting any data was the additional work of recording and reporting data weekly. Despite the fact that they were informed about the study both orally and in writing before signing up for participation, after randomization many of the coaches in the excluded clubs realized that the extra work would be too time consuming.

With respect to the internal validity, we found no differences between the two groups in their training or match exposure during the study. The coaches in both groups reported injuries and individual training and match participation prospectively on weekly registration forms according to pre-specified protocols and accepted injury definitions (Fuller et al., 2006). Because we recorded individual exposure we could adjust for playing time, which can vary greatly among players. This adjustment may be important as the best players play more games than substitutes and they may also train more. Individual exposure also takes censorship into account, such as abbreviated lengths of follow up for reasons other than injury (e.g. illness, moving, quitting the sport) (Bahr & Holme, 2003). Another advantage of this approach is that it provides accurate data about each player's exposure to the intervention, in this case the injury prevention program.

Injury recorders, who were blinded to group allocation, interviewed the injured players based on a standardized injury questionnaire as soon as possible after the weekly registration form was received. Even so, there is a possibility that injuries may have been overlooked by the coaches, although this is less likely for more severe injuries such as knee and ankle sprains. Our definition of reportable injury embraced any injury that occurred during a scheduled match or training session, causing the player to be unable to fully take part in the next match or training session (Fuller et al., 2006). Given the individual activity logs kept by the coaches, it is therefore unlikely that injuries would go unreported, and we see no reason to expect a reporting bias between the intervention and control groups. Our method should ensure good reliability and validity of the injury and exposure data.

The intention-to-treat analysis documented that the inflation factor for cluster effects was higher than our power calculation estimate (2.7 vs. 1.8). We based the inflation factor estimation on the incidence of lower extremity injuries in our previous study on a similar sample (Steffen et al., 2008c). Yet our results indicate that we may have underestimated the number of players we needed to establish possible intervention effects. This is also supported by the larger confidence intervals of the rate ratios calculated from the Cox regression analysis (taking cluster randomization into account) than the simpler Poisson regression model (assuming constant hazard per group) (see Paper I for details). In addition, our power calculation was based on a team dropout rate of 15% when the actual dropout rate was 25.6%.

A strength of the compliance study is that the compliance was recorded both among teams and individual players, providing a detailed account of the acceptance of the intervention. In addition, the sample size of both players and coaches was large and the follow-up period was one complete football season. With respect to the coach interviews, the main objective was to identify the attitudes and beliefs towards injury prevention training among the coaches, but we also wanted to evaluate the warm-up program and its exercises. As a consequence, the interviews were conducted after the season. However, the perceived risk of injury can easily influence the attitudes towards injury prevention training (Ajzen & Fishbein, 1980; Ajzen, 1985), hence, it would have been more appropriate to assess attitudes before the season and to evaluate the content of the program after the season.

Regarding the relationship between coach attitudes, compliance, and team injury risk, only coaches who completed the recording of compliance and injuries were included in the analyses. Although the most common barrier to study participation reported by coaches was the additional work of data recording and reporting, some teams may have dropped out due to low motivation towards the intervention program. Hence, coach attitudes to the program may be less favorable than that reported by the study participants.

Skill level and risk of injury (Paper III)

Of the 82 teams entering, 56 teams completed the study of the relationship between skill level and risk of injury in young female players (68%, 1034 players).

In general, skilled players were at greater risk of injury across the different skill attributes (Table 11). The injury incidence among highly skilled players varied from 4.4 to 4.9 injuries per 1000 player hours (across the 12 skill attributes), compared with 2.8 to 4.0 injuries per 1000 player hours among the players with low skill. With respect to technical attributes, players skilled in ball receiving, passing and shooting, heading, and tackling sustained more injuries overall, acute injuries, and contact injuries than the players with poor technique. Furthermore, players with good dribbling technique experienced a two-fold risk of contact injuries compared with poor dribblers.

When looking at the tactical components we find similar results. The players who made good tactical decisions in defense experienced a significantly higher risk of all the tested injury outcomes compared with players who made poor defensive decisions. Correspondingly, players who made good decisions when in possession of the ball were at higher risk of all the injury outcomes, except non-contact injuries.

Regarding the physiological attributes, the most distinctive finding was that physically strong players experienced a higher risk of injuries overall, injuries to the lower extremity, acute injuries, and contact injuries compared with physically weaker players.

Table 11. Relative risk of injury in high-skilled players compared with low-skilled players. Values are rate ratios with 95% confidence intervals.

	Injuries overall	Lower extremity injuries	Acute injuries	Contact injuries	Non-contact injuries
Technical attributes					
Ball receiving	1.55 [1.04-2.31]*	1.48 [1.00-2.19]	1.64 [1.06-2.53]*	3.19 [1.91-5.32]**	0.96 [0.58-1.58]
Passing & shooting	1.82 [1.26-2.63]**	1.64 [1.13-2.38]**	1.99 [1.31-3.03]**	3.13 [1.83-5.35]**	1.10 [0.74-1.64]
Heading (timing, power)	1.50 [1.13-2.00]**	1.56 [1.14-2.14]**	1.53 [1.11-2.11]**	1.77 [1.25-2.50]**	1.24 [0.82-1.87]
Dribbling	1.27 [0.91-1.77]	1.32 [0.94-1.86]	1.23 [0.86-1.75]	2.10 [1.37-3.22]**	0.93 [0.59-1.46]
Tackling	1.70 [1.18-2.45]**	1.68 [1.13-2.49]*	1.83 [1.22-2.73]**	2.37 [1.42-3.97]**	1.18 [0.79-1.78]
Tactical attributes. Decision-making when					
in ball possession (offensive)	1.62 [1.08-2.45]*	1.55 [1.01-2.36]*	1.66 [1.03-2.67]*	3.12 [1.63-5.97]**	0.95 [0.62-1.45]
not in ball possession (off.)	1.30 [0.92-1.85]	1.33 [0.93-1.91]	1.41 [0.98-2.03]	2.07 [1.34-3.20]**	0.93 [0.62-1.40]
in defense	1.81 [1.23-2.65]**	1.84 [1.20-2.84]**	1.79 [1.17-2.73]**	1.95 [1.19-3.18]**	1.62 [1.01-2.61]*
Physiological attributes					
Endurance	1.18 [0.84-1.66]	1.28 [0.91-1.80]	1.21 [0.83-1.76]	1.45 [0.90-2.34]	0.89 [0.56-1.43]
Speed/agility	1.21 [0.90-1.61]	1.36 [1.00-1.85]*	1.22 [0.89-1.67]	1.24 [0.82-1.89]	1.12 [0.77-1.64]
Strength	1.62 [1.18-2.22]**	1.57 [1.13-2.17]**	1.72 [1.22-2.44]**	2.15 [1.34-3.44]**	1.25 [0.86-1.82]
Coordination/balance	1.19 [0.79-1.79]	1.21 [0.79-1.86]	1.32 [0.88-1.99]	1.65 [1.04-2.63]*	0.92 [0.53-1.57]

Rate ratios calculated from Cox model according to method of Lin & Wei (1989)
*$P<0.05$, **$P<0.01$

The data on the relationship between football skills and risk of injury in football is equivocal (Dvorak et al., 2000; Östenberg & Roos, 2000; Söderman et al., 2001b; Árnason et al., 2004b; Emery et al., 2005b; Le Gall et al., 2008a; Severino et al., 2009). In youth football, Emery et al. (2005b) found no association between the risk of injury and the dynamic balance, vertical jump height, and endurance of female and male players 12 to 18 years of age. In male youth football, Le Gall et al. (2008a) reported no difference in the overall risk of injury between players acquiring a professional contract and those who did not. Yet, a higher risk of moderate and major injuries was found in the non-professionals, while the professionals sustained more injuries to the lower extremity, contusions to the lower leg, minor injuries, and re-injuries. The latter results are supported by Severino et al. (2009), who in 11- to 12-year old males found that injured players were better at ball juggling, dribbling, agility, and anaerobic performance.

It is difficult to suggest reasons for the higher risk of injury in the skilled players compared with their less skilled teammates. Previously, it has been argued that technically skilled players may be less injury-prone due to their ability to efficiently control and pass the ball before being challenged by the opposing player (Ekstrand & Karlsson, 1998). Likewise, tactically skilled players may be protected from injury, because they possess the ability to recognize potentially hazardous situations before they occur, and thus avoid them (Schwebel et al., 2007). Although these theories intuitively seem valid, they do not account for the fact that skilled players have more ball possession, and consequently are more exposed to tackles and other duels (Schwebel et al., 2007; Le Gall et al., 2008a; Steffen et al., 2009). This rationale is reflected by our findings; players skilled in ball receiving, passing and shooting, and decision-making when in ball possession, experienced a threefold risk of contact injury. In our analyses, we have corrected for exposure, estimated as the number of hours of match and training exposure. In this way, the fact that skilled players are more likely to be selected for games has been adjusted for. However, highly skilled players are most likely also more involved in the game, more prone to tackles and foul play, and hence, at greater risk of injury than their less skilled counterparts. Although generally not feasible in youth football, notational analysis tools (Thomas et al., 2009) provide the opportunity to record whether skilled players are more involved in game situations that entail a higher risk of injury, such as tackles.

Previously, it has been shown that the risk of injury in young female players increases by 12% for every successive year of participation in organized football (Steffen et al., 2008b). Moreover, previous injuries, as well as symptoms from previous injuries, make the player more susceptible to re-injuries (Emery et al., 2005b; Kucera et al., 2005; Steffen et al., 2008b). Although these factors were not recorded in the current study, it remains possible that compared with their less skilled teammates, the skilled players not only played more football during the season, but also started playing football at an earlier age. Furthermore, key players may experience higher external pressure or be more motivated to quickly return to play after an injury. Inadequate rehabilitation and premature return to play may increase the risk of exacerbations or re-injuries (Waldén et al., 2005a) and may thus lead to a higher injury risk in skilled players.

Methodological considerations (Paper III)

Our study differs from previous studies in that skill was assessed in relation to the skill level of teammates, and not players from other leagues or teams. Hence, if a player was evaluated to be highly skilled, she was better than her low-skilled teammates, but not necessarily better than low-skilled players on other teams. Consequently, direct comparison with findings in previous studies with different methodology can be difficult.

The main limitation of the study is that the recording of skills was conducted retrospectively, two months after the recording of injuries was completed. This may add uncertainty as to whether a player's level of skill is a possible cause or a consequence of the injury (Bahr & Holme, 2003) and introduces a potential assessment bias because the coaches knew which players were injured during the previous season. However, there is also an obvious advantage of recording the level of skill retrospectively; it allows for an overall assessment of the players' performance throughout the course of a complete season. Nevertheless, skill is not a static variable, and potential change in the different skill attributes of the players during the season was not accounted for. In future studies, it would be advisable to measure the skills before the injuries occur, and follow up with prospective repeated assessments throughout the season.

Another limitation is that the skill assessment approach was not validated. In future studies, the use of established tests for passing (Ali et al., 2007; 2008), shooting (Ali et al., 2007), dribbling (Rösch et al., 2000), and physical performance (Léger & Lambert, 1982; Krustrup et al., 2003; Impellizzeri et al., 2008) should be considered. Nevertheless, football is a complex sport where performance is determined by a wide range of technical, tactical, and physiological skill attributes. It is questionable whether performance in football can be assessed strictly using objective testing (Vaeyens et al., 2006), and the qualitative assessment of a coach can therefore be useful.

Turf type and risk of injury in Norway Cup (Paper IV)

From the Norway Cup 2005 through 2008 data were collected from 7848 matches; 5491 (70%) played by boys and 2357 (30%) by girls. The total exposure to football was 62 597 match hours; 6022 (10%) on artificial turf and 56 575 (90%) on grass. A total of 2454 injuries were recorded; 206 (8%) on artificial turf and 2248 (92%) on grass.

The main findings were that there was no difference in the risk of acute injuries overall or acute time-loss injuries between boys and girls playing tournament football on third generation artificial turf compared with grass. The overall incidence of injuries was 39.2 ± 0.8 per 1000 match hours; 34.2 ± 2.4 on artificial turf and 39.7 ± 0.8 on grass. The incidence of time-loss injuries was 4.3 ± 0.3 per 1000 match hours; 4.2 ± 0.8 on artificial turf and 4.4 ± 0.3 on grass. After adjusting for the potential confounders age and gender there was no difference in the overall risk of injury (odds ratio 0.93; 95% confidence interval 0.77 to 1.12, P=0.44) or in the risk of time-loss injury (odds ratio 1.05; 95% confidence interval 0.68 to 1.61, P=0.82) between artificial turf and grass.

This is the first study to assess the relationship between the turf types and risk of injury in both male and female youth football. The main results are consistent with the conclusions in previous studies evaluating the risk of injury on third-generation artificial turfs and grass in male and female elite players (Ekstrand et al., 2006; 2010), male and female college players (Fuller et al., 2007a; 2007b), 14-16 year old female players (Steffen et al., 2007), and 12-17 year old male players

(Aoki et al., 2010). The only significant difference in injury pattern in the current study was a lower risk of ankle injuries on artificial turf and a higher risk of back and spine injuries, as well as injuries to the shoulder and clavicle (Table 12). However, interpretation of these differences should be made with caution. Comparison of injury incidences between surfaces for specific injury sub-groups is restricted by small numbers, and the possibility of type II error resulting from limited data must be considered.

Table 12. Number, incidence, and risk of acute injuries on artificial turf and grass.

	Artificial turf		**Grass**		**RR (95% CI)**	**Adjusted OR (95% CI)†**
	Injuries	Incidence	Injuries	Incidence		
Injury type						
Contusion	83	13.8 ± 1.5	883	15.6 ± 0.5	0.88 [0.71-1.11]	0.91 [0.69-1.19]
Sprain	6	1.0 ± 0.4	123	2.2 ± 0.2	0.46 [0.20-1.04]	0.52 [0.23-1.18]
Strain	13	2.2 ± 0.6	168	3.0 ± 0.2	0.73 [0.42-1.28]	0.88 [0.50-1.52]
Fracture	2	0.3 ± 0.2	14	0.2 ± 0.1	1.34 [0.31-5.91]	1.31 [0.30-5.78]
Dislocation	1	0.2 ± 0.2	20	0.4 ± 0.1	0.47 [0.06-3.50]	0.47 [0.06-3.49]
Abrasion/laceration	5	0.8 ± 0.4	55	1.0 ± 0.1	0.85 [0.34-2.13]	0.89 [0.36-2.25]
Injury location						
Lower body	116	19.3 ± 1.8	1596	28.2 ± 0.7	0.68 [0.57-0.82]**	0.81 [0.66-1.01]
Foot	25	4.2 ± 0.8	276	4.9 ± 0.3	0.85 [0.57-1.28]	1.05 [0.70-1.58]
Ankle	26	4.3 ± 0.8	476	8.4 ± 0.4	0.51 [0.36-0.76]**	0.59 [0.40-0.88]**
Lower leg	14	2.3 ± 0.6	189	3.3 ± 0.2	0.70 [0.40-1.20]	0.71 [0.41-1.24]
Knee	28	4.6 ± 0.9	314	5.6 ± 0.3	0.84 [0.57-1.23]	0.96 [0.65-1.42]
Thigh	12	2.0 ± 0.6	236	4.2 ± 0.3	0.48 [0.27-0.85]*	0.69 [0.41-1.15]
Hip	4	0.7 ± 0.3	48	0.8 ± 0.1	0.78 [0.28-2.17]	0.99 [0.39-2.50]
Groin	7	1.2 ± 0.4	57	1.0 ± 0.1	1.15 [0.53-2.53]	0.85 [0.34-2.13]
Upper body	88	14.6 ± 1.6	601	10.6 ± 0.4	1.38 [1.10-1.72]**	1.23 [0.93-1.61]
Back/spine	18	3.0 ± 0.7	76	1.3 ± 0.2	2.23 [1.33-3.72]**	1.92 [1.10-3.36]*
Stomach/chest	10	1.7 ± 0.5	108	1.9 ± 0.2	0.87 [0.46-1.66]	1.02 [0.54-1.90]
Arm/hand/fingers	11	1.8 ± 0.6	65	1.1 ± 0.1	1.59 [0.84-3.01]	1.16 [0.62-2.18]
Shoulder incl. clavicle	7	1.2 ± 0.4	29	0.5 ± 0.1	2.27 [0.99-5.18]	2.32 [1.01-5.31]*
Neck	4	0.7 ± 0.3	53	0.9 ± 0.1	0.71 [0.26-1.96]	2.19 [0.83-5.80]
Head	38	6.3 ± 1.0	270	4.8 ± 0.3	1.32 [0.94-1.86]	1.23 [0.84-1.80]
Severity						
Minimal injuries (1-3 days)	17	2.8 ± 0.7	150	2.7 ± 0.2	1.07 [0.65-1.76]	1.12 [0.66-1.89]
Mild injuries (4-7 days)	6	1.0 ± 0.4	39	0.7 ± 0.1	1.45 [0.61-3.41]	1.50 [0.63-3.56]
Moderate injuries (8-28 days)	1	0.2 ± 0.2	37	0.7 ± 0.1	0.25 [0.04-1.85]	0.28 [0.04-2.05]
Severe injuries (>28 days)	1	0.2 ± 0.2	21	0.4 ± 0.1	0.45 [0.06-3.33]	0.49 [0.07-3.69]

Abbreviations: RR, rate ratio; CI, confidence intervals; OR, odds ratio
*P<0.05, **P<0.01
†Adjusted for age and gender

The two main factors involved in surface-related football injuries are the friction between the surface and the shoe and the stiffness of the surface (Nigg & Yeadon, 1987). Although the grass fields in Norway Cup are mowed before the start of the tournament, they are often characterized by a soft, but uneven surface. Such rough field conditions can play a role in an injury mechanism for ankle sprains, which may explain the increased risk of ankle injuries found on grass. Contrary, Ekstrand et al. (2006; 2010) found that elite male players had a higher risk of ankle injuries on artificial turf. However, the grass fields in professional football are of much higher standard than the grass fields in this youth amateur football tournament.

Minor abrasions and friction burns have been reported to be more common on artificial turf, albeit on older generations (Winterbottom, 1985; Nigg & Segesser, 1988; Ekstrand & Nigg, 1989; Gaulrapp et al., 1999). However, by using the broad injury definition we could examine this, and our findings indicate that such injuries were not a problem with the new generation of artificial turfs. Furthermore, it should be noted that although ”third-generation artificial turf” is the collective term for the latest artificial surfaces, there are several manufacturers who deliver various brands of artificial turfs. The brands may have dissimilar surface stiffness and friction, depending on the fibre length and thickness, the type and amount of rubber granules, and whether an optional shock-absorbing rubber pad is molded underneath the surface.

Methodological considerations (Paper IV)

A strength of the study is that it spanned across four consecutive tournaments from 2005 to 2008, including almost 8000 matches and more than 60 000 match hours. Furthermore, the time span of our data collection minimized the risk of biased results with respect to the playing fields being influenced by a particular weather condition. Throughout the four tournaments the players played both on soft and slippery surfaces resulting from rain, as well as on harder surfaces with more friction resulting from sun and dry weather conditions.

The number of matches played during the Norway Cup-tournament (almost 2000 11-a-side matches played in less than a week) makes it difficult to survey the injury frequency using medically trained personnel. The main limitation of the study is that the data collection depended on the coaches and the referees. Although they received information detailing the injury recording procedures they were not medically trained to ensure good validity and reliability in determining the presence of injury, let alone determining the diagnosis and prognosis. The results concerning the type and severity of injury must therefore be interpreted with caution. Furthermore, when studying epidemiology or etiology of football injuries the time-loss definition of injury is most commonly used. However, we employed the broader definition of injury from the consensus statement, which includes all painful conditions or physical complaints irrespective of the need for medical attention or time loss from football activities (Fuller et al., 2006). A limitation of this definition is that it will include a number of physical complaints and bodily conditions that may not significantly affect performance. Even so, in the current study this definition was likely to provide better reliability in the data collection, compared with using the time-loss definition, which would rely on the coaches' ability to estimate whether an injury would lead to absence from training and matches.

To examine to which degree the coaches recorded all occurring injuries according to the injury definition, we conducted a compliance study in the 2005 tournament. Three physicians from our research centre observed and recorded all physical complaints and other events possibly related to injury in 49 randomly selected matches. In cases where it was difficult to ascertain whether an injury had occurred, the physician contacted and interviewed the respective player immediately after the match. The results showed that the coaches recorded less than half (46%) of the injuries that occurred. With respect to internal validity, however, we could not detect any systematic errors in the coaches' recording of injuries between the two turf types.

Perspectives

In our injury prevention study we used female youth football (aged 13 to 17 years) as a model. We do not know if the results can be generalized to both genders, other age groups, or other youth sports. However, preventive programs of similar principles were effective in senior elite football (Caraffa et al., 1996; Árnason et al., 2008), male youth football (Junge et al., 2002), and in both sexes in other sports (Hewett et al., 1999; Emery et al., 2005a). Furthermore, in youth team handball Olsen et al. (2005) also documented a substantial decrease in the rate of injuries as a result of a similar structured warm-up program. However, football differs from many other team sports in that there is a much higher potential for direct contact to the lower extremities. Nevertheless, the mechanisms for serious knee injuries appear to be comparable across many sports (mostly non-contact, resulting from pivoting and landing movements). It therefore seems reasonable to assume that the program used in the present study also could be modified for use in other similar sports, at least for some types of injury. One of the goals in sports injury prevention should be to develop less vulnerable movement patterns. Thus, it may be easier to work with even younger players who have not yet established their basic motion patterns. We therefore suggest that programs aiming to improve strength, awareness and neuromuscular control of static and dynamic movements, be implemented as soon as they start playing organized football.

Knowledge of factors that influence compliance with an intervention is still limited. Our study is one of few that have aimed to identify these factors. The findings demonstrated that attitudes towards injury prevention training indeed are associated with the rate of uptake of an intervention. Attitudes are developed from an early age. It may be important to implement injury prevention training as soon as children start participating in organized sports to make it a natural part of their training routines. It is also necessary to increase the understanding of the benefits of injury prevention among coaches in both youth and elite sports. Thus, injury prevention training ought to be a core element of coach education and training programs in football and other sports.

Furthermore, when recording and reporting compliance in team sports there should be a distinction between compliance among teams and among individual players. The compliance of a team is highly dependent on the motivation, choices, and actions of the head coach. Recording individual participation, on the other hand, reveals the rate of uptake and actual usage of the intervention for each player. Thus, recording of individual compliance is necessary to investigate how compliance influences the effect of an intervention and to identify possible exposure-response relationships. Recording team and player compliance together will provide detailed data on the overall compliance with the intervention (Figure 6), and such methods should be applied in future research.

In terms of injury risk factors, our results suggest that skill level should be addressed as a possible confounder in studies on other risk factors for injury. However, because skill level was registered in relation to the skill level of teammates, our findings might not be valid within populations consisting of multiple teams or leagues. Teams in female youth football are often characterized by large variations in skill level, larger than on the senior level and in male football. Thus, we do not know if the results can be generalized to both genders or other age groups.

Considering the limited knowledge about football skills as a potential injury risk factor in football, our findings need to be confirmed by subsequent studies in youth football, as well as in adult cohorts. Furthermore, by implementing actual game play measures (match statistics) in future research we can ascertain whether skilled players actually are more involved in game situations that entail a higher risk of injury. The disproportionate high risk of contact injuries in players who excel in youth football does in any case seem to warrant injury prevention to focus more on the injuries occurring from tackles and contact situations. Stricter interpretation of the fair play rules and better refereeing may be important means to protect the ”Messis” and ”Martas” (FIFA, 2009) of tomorrow from career-ending injuries and allow them to hone their skills throughout adolescence to achieve their optimal potential in adulthood. Previously proposed measures to prevent contact injuries include modification and enforcement of the Laws of the Game, the referees' interpretation of the rules, as well as the coaches' and players' attitudes towards fair play and high-risk game situations (Andersen et al., 2004b; Árnason et al., 2004c; Fuller et al., 2004a; 2004b). To our knowledge, no risk factor studies or preventive measures specifically aimed at contact injuries have been implemented in female youth football. However, it has been shown in international female tournaments that the decision of the referee does not reflect the injury risk of sliding-in tackles (Tscholl et al., 2007b). Thus, it seems unreasonable to expect referees on a lower level to make correct decisions based on a subjective judgment of injury risk.

Finally, our study addressing the risk of injury on artificial turf and grass in football supports the findings in previous investigations. Although there are some conflicting results regarding subgroups of injuries, the overall risk of acute injury seems to be similar on the two surfaces. However, the significance of artificial turf in the etiology of overuse injuries is still uncertain. For instance, it has been speculated that higher ground stiffness in particular can have an influence on overuse injuries (Ekstrand & Nigg, 1989). Furthermore, in our sample (Norway Cup) all teams play on both artificial turf and grass, and continuously switch between the two surfaces. Studies assessing the injury risk on previous generations of artificial turf have discussed whether players' lack of adaptation to a surface and rapid changes between different types of playing surfaces is a precursor to overuse injury, such as lower limb and lower back pain (Ekstrand & Gillquist, 1983b; Engebretsen & Kase, 1987; Ekstrand & Nigg, 1989; Hagel et al., 2003). However, such theories are hard to test in epidemiological studies using the traditional methodology to record injuries. By definition overuse injuries occur over time with a gradual onset, and the traditional study design and methodology does not allow for attribution of overuse injury to a specific event or a particular turf type. Even if a player first experiences symptoms during a specific match, the injury may have gradually been incurred as a result of long-term exposure to another turf type, rapid changes between different turf types, or other factors. To investigate whether overuse injuries are associated with a specific turf type, the ideal design would be a randomized controlled trial where players are randomized to train and play matches exclusively on either artificial turf or grass. For practical reasons, such a study is not feasible and will probably never take place. A more realistic approach would be to compare teams training and playing their home matches on artificial turf to teams who mainly train and play on grass (Ekstrand et al., 2006; 2010; Aoki et al., 2010). In planning new studies one should in any case consider adopting novel methodology developed to record and quantify the risk and severity of overuse injuries in sport (Bahr, 2009). Through more advanced statistical modeling it may also be possible to detect if there is an increased injury risk associated with rapid switches in playing surface.

Conclusions

1. Although the primary outcome of reduction in lower extremity injury did not reach significance, the risk of injury overall was reduced by about one third and the risk of severe injuries by as much as one half. This indicates that a structured warm-up program can prevent injuries in young female football players.

2. The compliance among players and teams with the 11+ injury prevention program was high. Players with high compliance appeared to benefit in terms of fewer injuries. Positive coach attitudes were correlated with high compliance and lower injury risk. When embedding injury prevention into team training sessions, recording both team and player compliance is necessary to document overall compliance and exposure-response relationships.

3. Players with good technical, tactical, and physiological football skills were at greater risk of injury than their less skilled teammates. Stricter enforcement of the Laws of the Game and modification of coaches' and players' attitudes towards fair play and high-risk game situations may be needed.

4. A prospective cohort study over four years showed no difference in the overall rate of acute injury among boys and girls playing tournament football on third-generation artificial turf compared with grass.

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Errata

The following corrections were made to the thesis after it was submitted:

- The published version of Paper III replaced the previous version which was in press.
- Appendices 1-5 were added.

Papers I-IV

Paper I

BMJ

RESEARCH

Comprehensive warm-up programme to prevent injuries in young female footballers: cluster randomised controlled trial

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Cite this as: *BMJ* 2008;337:a2469
doi:10.1136/bmj.a2469

ABSTRACT

Objective To examine the effect of a comprehensive warm-up programme designed to reduce the risk of injuries in female youth football.

Design Cluster randomised controlled trial with clubs as the unit of randomisation.

Setting 125 football clubs from the south, east, and middle of Norway (65 clusters in the intervention group; 60 in the control group) followed for one league season (eight months).

Participants 1892 female players aged 13-17 (1055 players in the intervention group; 837 players in the control group).

Intervention A comprehensive warm-up programme to improve strength, awareness, and neuromuscular control during static and dynamic movements.

Main outcome measure Injuries to the lower extremity (foot, ankle, lower leg, knee, thigh, groin, and hip).

Results During one season, 264 players had relevant injuries: 121 players in the intervention group and 143 in the control group (rate ratio 0.71, 95% confidence interval 0.49 to 1.03). In the intervention group there was a significantly lower risk of injuries overall (0.68, 0.48 to 0.98), overuse injuries (0.47, 0.26 to 0.85), and severe injuries (0.55, 0.36 to 0.83).

Conclusion Though the primary outcome of reduction in lower extremity injury did not reach significance, the risk of severe injuries, overuse injuries, and injuries overall was reduced. This indicates that a structured warm-up programme can prevent injuries in young female football players.

Trial registration ISRCTN10306290.

INTRODUCTION

Football (soccer) is the most popular team sport in the world. There are already more than 265 million registered players, and the number of participants is continuing to grow.[1] In particular, the number of women players is increasing rapidly.[1] Playing football, however, entails a substantial risk of injury, and studies on elite and non-elite female footballers have reported rates of injury similar to those in men,[2-11] the most common being injuries to the knee and ankle ligament and thigh muscle strains.[2-9 11 12] Women might even be at greater risk of serious injury than men; the rate of anterior cruciate ligament injuries is three to five times higher for girls than for boys.[13 14]

The high injury rate among football players in general and female players in particular constitutes a considerable problem for the player, the club, and—given the popularity of the sport—for society at large. Health consequences are seen not just in the short term but also in the dramatic increase in the risk of early osteoarthritis.[15-17] Despite the urgent need to develop programmes to prevent knee and ankle injuries in footballers, there exist only a few small or non-randomised studies on prevention of injury in female football players.[18-20]

In a recent randomised controlled trial, we examined the effect of a structured training programme ("The 11")[21] over one season among 2000 female players aged 13-17.[22] The intervention consisted of exercises focusing on core stability, balance, dynamic stabilisation, and eccentric hamstring strength. We found no difference in the injury risk between the intervention group and control group, though the study was limited by low compliance among the intervention teams.

This led us to develop an exercise programme to improve both the preventive effect of the programme and the compliance of coaches and players. The revised programme ("The 11+") included key exercises and additional exercises to provide variation and progression. It also included a new set of structured running exercises that made it better suited as a comprehensive warm-up programme for training and matches.

We conducted a randomised controlled trial to examine the effect of the revised programme on rates of lower extremity injury in young female footballers. To minimise contamination bias within clubs, we used a cluster randomised design.

METHODS

We randomised 125 clubs who agreed to participate in the study to the intervention or control group. All teams from one club were randomised to the same treatment arm. Five clubs included two teams each. The statistician (IH) who conducted the randomisation did not take part in the intervention. Box 1 provides details of the procedure used to recruit clubs.

We informed clubs allocated to the intervention group that they would receive a programme of warm-up exercises used to prevent injuries and enhance performance. We asked the clubs in the control group to warm up as usual during the season and informed them that, if the intervention programme prevented injuries, they would receive the same programme as the intervention group in the subsequent season.

Box 1 Recruitment of clubs to the study

- All of the 181 clubs in the 15-16 year divisions from the south, east, and middle of Norway, organised by the regional districts of the Norwegian Football Association, received an invitation to participate in the study during one eight month season (March to October 2007)
- To be included in the study, clubs had to carry out at least two training sessions a week in addition to match play. The clubs practised two to five times a week and played between 15 and 30 matches during the season
- All clubs were recruited in January and February 2007. Club enrolment registries for the 2007 league system were obtained from the regional districts of the Norwegian Football Association, and coaches were informed by telephone about the purpose and the design of the study. After oral consent, a letter containing a more thorough description of the study and a study enrolment return form was sent out to the coaches, who also informed the players
- Player participation was voluntary

Intervention

An expert group convened by the international football federation (FIFA), with representatives from the Oslo Sports Trauma Research Center, the Santa Monica Orthopaedic and Sports Medicine Research Foundation, and the FIFA Medical Assessment and Research Centre, developed the warm-up programme. Before the start of the study one club tested the programme. It consisted of three parts (table 1). The initial part was running exercises at slow speed combined with active stretching and controlled contacts with a partner. The running course included six to ten pairs of cones (depending on the number of players) about five to six metres apart (length and width). The second part consisted of six different sets of exercises; these included strength (fig 1), balance, and jumping exercises, each with three levels of increasing difficulty. The final part was speed running combined with football specific movements with sudden changes in direction.

At the start of the pre-season, February to mid-April 2007, we invited the coaches and team captains from all clubs in the intervention group to a three hour instructional course in which we introduced the warm-up programme. Instructors from the Oslo Sports Trauma Research Centre arranged courses at different locations in each of the eight regional districts. The instructors had been familiarised with the programme during a seminar, where they received theoretical and practical training in the programme and instruction in how to teach the exercises to the coaches and team captains.

The coaches received an instructional DVD showing all of the exercises in the programme, a loose leaf exercise book, and small exercise cards attached to a neck strap. In addition, the coaches and every player received a poster explaining every exercise. The information material detailed each exercise and explained the proper form for each, as well as common biomechanical mistakes. It also described the principles of progression in the exercise prescription. We asked the coaches to use the complete exercise

Fig 1 | Two examples of strength exercises. Top: side plank exercise. Bottom: the "Nordic hamstring lower"

programme as the warm up for every training session throughout the season and to use the running exercises in the programme as part of their warm up for every match.

When introducing the programme to the clubs, our main focus was to improve awareness and neuromuscular control during standing, running, planting, cutting, jumping, and landing. We encouraged the players to concentrate on the quality of their movements and put emphasis on core stability, hip control, and proper knee alignment to avoid excessive knee valgus during both static and dynamic movements (fig 2). We asked the coaches and the players to watch each other closely and give feedback during training. Once players were familiar with the exercises the programme took about 20 minutes to complete.

Throughout the season, researchers contacted the coaches regularly by email and telephone; this allowed the coaches to ask questions and provide feedback with respect to the warm-up programme and injury and exposure registration. It also helped us to identify clubs that were not complying with the protocol or where additional motivational measures, such as site visits, were needed to increase compliance. Clubs in both groups were offered an incentive in the form of high quality footballs, provided they completed data registration throughout the study period. Despite these measures, 13 clubs in the intervention group did not start the warm-up programme nor did they deliver any data on injury or exposure (fig 3). Nineteen clubs in the control group did not provide any data.

Table 1 | Revised warm-up exercise programme used to prevent injury in young female footballers

Exercise	Repetitions
I. Running exercises, 8 minutes (opening warm up, in pairs; course consists of 6-10 pairs of parallel cones):	
Running, straight ahead	2
Running, hip out	2
Running, hip in	2
Running, circling	2
Running and jumping	2
Running, quick run	2
II. Strength, plyometrics, balance, 10 minutes (one of three exercise progression levels each training session):	
The plank:	
Level 1: both legs	3×20-30 seconds
Level 2: alternate legs	3×20-30 seconds
Level 3: one leg lift	3×20-30 seconds
Side plank:	
Level 1: static	3×20-30 seconds (each side)
Level 2: dynamic	3×20-30 seconds (each side)
Level 3: with leg lift	3×20-30 seconds (each side)
Nordic hamstring lower:	
Level 1	3-5
Level 2	7-10
Level 3	12-15
Single leg balance:	
Level 1: holding ball	2×30 seconds (each leg)
Level 2: throwing ball with partner	2×30 seconds (each leg)
Level 3: testing partner	2×30 seconds (each leg)
Squats:	
Level 1: with heels raised	2×30 seconds
Level 2: walking lunges	2×30 seconds
Level 3: one leg squats	2×10 (each leg)
Jumping:	
Level 1: vertical jumps	2×30 seconds
Level 2: lateral jumps	2×30 seconds
Level 3: box jumps	2×30 seconds
III. Running exercises, 2 minutes (final warm up)	
Running over pitch	2
Bounding run	2
Running and cutting	2

Outcome measures

We defined the primary outcome as an injury to the lower extremity (foot, ankle, lower leg, knee, thigh, groin, and hip) and secondary outcomes as any injury, or an injury to the ankle, knee, or other body parts. We included all injuries reported after an intervention club had completed the first prevention training session (matched with the same date in a control club) to compare the risk of injury between the groups.

Exposure and injury registration

The coaches reported injuries and details of an individual player's participation for each training session and match, as well as to what extent the warm-up programme was carried out each session (intervention clubs) on weekly registration forms throughout the study period. These were submitted by email, mail, or fax to the research centre. Data on players who dropped out during the study period were included for the entire period of their participation.

At the research centre one physical therapist and one medical student, who were blinded to group allocation, recorded injuries. They were given specific training on the protocols for injury classification and injury definitions (box 2) before the start of the injury registration period. Every injured player was contacted to assess aspects of the injury based on a standardised injury questionnaire.[23] In most cases, players were contacted within four weeks (range one day to five months) after the injury. Box 2 shows the definitions we used to register injuries. These are in accordance with the consensus statement on injury definitions and data collection procedures.[24]

Sample size

We calculated our sample size on the basis of data on incidence of injury in young female footballers in Norway during the 2005 season.[22] We estimated that 16% would incur an injury to the lower extremities and about 10-12% would injure a knee or ankle during one season. Given an estimated inflation factor for cluster effects because of randomisation by clubs of 1.8,[22] 900 players in each group would provide an acceptable power of 0.86 at the 5% significance level to detect a 40% reduction in the number of players with a lower extremity injury. Our model was based on 18 players

Fig 2 | Example of running exercise illustrating key objectives of all running, jumping, cutting, and landing exercises: core stability and correct lower extremity alignment. Left: correct technique; right: incorrect technique with pelvic tilt and knee valgus alignment to right

per club and a dropout rate of 15%, which means that we needed to include about 120 clubs with 2150 players.

Statistical methods

We conducted all statistical analyses according to a prespecified plan using Stata, version 10.0 (StataCorp, College Station, TX). We used the rate ratio of the risk of injury according to the intention to treat principle to compare the risk of an injury in the two groups. We used Cox regression for the primary and secondary outcomes and the robust calculation method of the variance-covariance matrix,[25] taking the cluster randomisation by clubs into account. Rate ratios were tested with the Wald test. One way analysis of variance was used to estimate the intracluster correlation coefficient to obtain estimates of the inflation factor for comparison with planned sample size. To calculate the number needed to prevent one injury we used the inverse of the difference between percentages of injured players in the two groups. We used one minus survival plots based on the Cox regression to evaluate possible delays of the injury prevention effects of the programme in the intervention group compared with the control group. We used a Poisson model, taking cluster effects into account, as a per protocol analysis to compare the rate ratios of risk of injury between players in the intervention group stratified into thirds of compliance according to the number of prevention sessions completed: low, intermediate, and high. The summary measure of injury incidence (i) was calculated according to the formula $i=n/e$, where n is the number of injuries during the study period and e the sum of exposure time expressed in player hours of match, training, or in total. We calculated confidence intervals of the rate ratio of the number of injuries in the intervention and control groups by a simple Poisson model, assuming constant hazard per group. Injury incidences are presented as means with standard errors. Rate ratios are presented with 95% confidence intervals. We regarded two tailed P values ≤0.05 as significant.

RESULTS

The final sample consisted of 52 clubs (1055 players) in the intervention group and 41 clubs (837 players) in the control group (fig 3). The players in the two groups were similar in age (15.4 (SD 0.7) years in both groups) and age distribution. The dropout rate was similar between the groups (23 (2.1%) *v* 24 (2.9%)).

Exposure and injury characteristics

Those in the intervention group played 49 899 hours of football (16 057 hours of matches and 33 842 hours of practice). The figure for the control group was 45 428 hours (14 342 and 31 086). During the eight month season, 301 (16%) of the 1892 players included in the study sustained a total of 376 injuries; 161 in the intervention group, 215 in the control group. There were 299 (80%) acute injuries and 77 (20%) overuse injuries. The overall incidence of injuries was 3.9 (SD 0.2) per 1000 player hours (8.1 (SD 0.5) in matches and 1.9 (SD 0.2) in training).

Effect of revised injury prevention programme

The rate ratio for players with a lower extremity injury between the intervention and the control group was 0.71 (0.49 to 1.03, P=0.072). There was a significantly lower risk of injuries overall, overuse injuries, and severe injuries in the intervention group (table 2). The reduction in the risk of match injuries, training injuries, knee injuries, and acute injuries (from 26% to 38%) did not reach significance. The degree of clustering at the club level (intracluster correlation coefficient) ranged from 0.028 to 0.096. The estimated inflation factor varied from 1.54 to 2.86. The number needed to treat to prevent one injury varied from 15 to 63 players. Figure 4 shows survival curves for lower extremity injuries and severe injuries in the two groups.

The mean age of injured players was 15.4 (SD 0.6) in the intervention group and 15.5 (SD 0.7) in the control group. Table 3 shows the most commonly injured

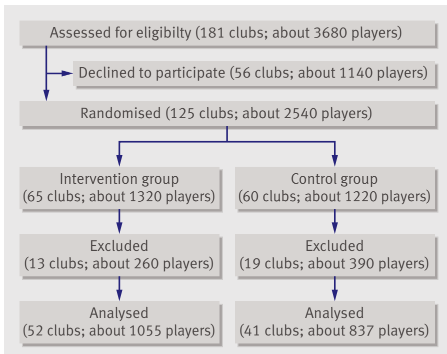

Fig 3 | Flow of club clusters and players through study

body parts and the type of acute and overuse injuries for both groups.

Compared with the control group, significantly fewer players in the intervention group had two or more injuries (rate ratio 0.51, 95% confidence interval 0.29 to 0.87), while a reduction in the risk of re-injuries did not reach significance (0.46, 0.20 to 1.01). Table 4 shows the severity distribution for different types of injury. The overall rate of injuries, as well as the rate of match injuries, training injuries, overuse injuries, and acute injuries, differed significantly. The rate of severe injuries, severe overuse injuries, and severe acute injuries was significantly lower in the intervention group.

Compliance with programme

The 52 clubs in the intervention group performed the injury prevention programme for 44 (SD 22, range 11-104) sessions (77%) throughout the season. The average player attendance for matches and training sessions was 11.7 (57.9% of all the players on the roster), which was similar to the average number who participated in the warm-up programme (12.0 (59.4%) of all the players on the roster). The average attendance in the control group was 12.2 (59.8% of all the players on the roster). None of the clubs in the control group reported performing structured warm-up exercises comparable with the intervention. The risk of injury was 35% lower in intervention players in the third with the highest compliance (2.6 (20. to 3.2) injuries/1000 player hours, mean (range 33-95) 49.2 sessions) compared with players in the intermediate third (4.0 (3.0 to 5.0) injuries/1000 player hours, mean 23.4 (15-32) sessions) (rate ratio 0.65, 0.44 to 0.94, P=0.02). The 32% reduction in risk of injury compared with the third with the lowest compliance (3.7 (2.2 to 5.3) injuries/1000 player hours, mean 7.7 (0-14) sessions) did not reach significance (rate ratio 0.68, 0.41 to 1.12, P=0.13).

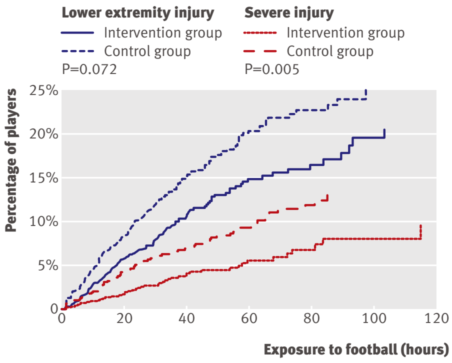

Fig 4 | Survival curves based on Cox regression for players with lower extremity injury and severe injury

Box 2 Operational definitions used in registration of injury

Reportable injury

- An injury occurred during a scheduled match or training session, causing the player to be unable to fully take part in the next match or training session.

Player

- A player was entered into the study if she was registered by the coach on the club roster to take part in the club's team competing in the 15 or 16 year divisions.

Return to participation

- The player was defined as injured until she was fully fit to take part in all types of training and matches.

Type of injury

- Acute: injury with sudden onset associated with known trauma
- Overuse: injury with gradual onset without known trauma
- Re-injury: injury of the same type and location sustained previously.

Severity

- Minimal injuries: absence from match and training for 1-3 days
- Mild injuries: absence from match and training for 4-7 days
- Moderate injuries: absence from match and training for 8-28 days
- Severe injuries: absence from match and training for more than 28 days.

Exposure

- Match exposure: hours of matches.
- Training exposure: hours of training.

In almost all cases, a doctor examined players with moderate or severe injuries. If there was any doubt about the diagnosis the player was referred to a sports medicine centre for follow-up, which often included imaging studies or arthroscopic examination. In cases of minimal or mild injuries, players were examined by a local physiotherapist or 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, and we had no influence on the time it took a player to return to club activities.

DISCUSSION

This randomised controlled trial of a structured warm-up programme in young female footballers showed that the risk of injury can be reduced by about one third and severe injuries by as much as one half. Although the rate ratios for the different outcome variables indicated a consistent effect on risk of injury across most types of injury, the primary outcome—lower extremity injury—did not reach significance when we adjusted for the cluster sampling. There was, however, a significant reduction in several secondary outcome variables, including the rate of severe injuries, overuse injuries, and injuries overall.

The effect of various intervention programmes designed to reduce the risk of injury to the lower extremities in young female footballers has been studied previously.[18-20 22] These studies, however, were either non-randomised, had small sample sizes, had low compliance, or had other important limitations.

Methodological considerations

The trial took place in the 15 and 16 year divisions from the south, east, and middle of Norway and recruited 69% of all clubs and players organised by the Norwegian Football Association in these areas. Of the 181 clubs assessed for eligibility, 56 declined to participate and 125 were randomised. During the recruitment of clubs, the most common barrier to participation that coaches reported was the additional work of registering and reporting data weekly. Other less common reasons for non-participation included a

Table 2 | Intention to treat analysis of warm-up exercise programme (intervention) in young female footballers. Values are numbers (percentages) of injured players

	Intervention group (n=1055)	Control group (n=837)	Intracluster correlation coefficient*	Inflation factor*	NNT	Rate ratio (95% CI)†	P value
All injuries	135 (13.0)	166 (19.8)	0.096	2.86	15	0.68 (0.48 to 0.98)	0.041
Match injuries	96 (9.1)	114 (13.6)	0.045	1.87	22	0.72 (0.52 to 1.00)	0.051
Training injuries	50 (4.7)	63 (7.5)	0.044	1.86	36	0.68 (0.41 to 1.11)	0.120
Lower extremity injuries	121 (11.5)	143 (17.1)	0.088	2.70	18	0.71 (0.49 to 1.03)	0.072
Knee injuries	33 (3.1)	47 (5.6)	0.028	1.54	40	0.62 (0.36 to 1.05)	0.079
Ankle injuries	45 (4.3)	49 (5.9)	0.026	1.50	63	0.81 (0.50 to 1.30)	0.378
Acute injuries	112 (10.6)	130 (15.5)	0.070	2.35	20	0.74 (0.51 to 1.08)	0.110
Overuse injuries	27 (2.6)	48 (5.7)	0.040	1.76	32	0.47 (0.26 to 0.85)	0.012
Severe injuries	45 (4.3)	72 (8.6)	0.028	1.54	23	0.55 (0.36 to 0.83)	0.005

NNT=number needed to treat.
*Generalised estimating equation model with clubs as cluster unit.
†Cox model calculated according to method of Lin and Wei,[25] which takes cluster randomisation into account.

reluctance to use the same warm-up programme for every training session and match and low priority for injury prevention. Thus, although we recruited a high proportion of eligible teams, the final sample probably included teams with more dedicated coaches. After inclusion, we had to exclude 13 intervention clubs and 19 control clubs because they did not deliver any data on injury or exposure. In most cases the coaches were volunteers, such as parents, and the most common reason for not reporting any data was the additional work of registering and reporting data weekly. Despite the fact that they were informed about the study both orally and in writing before signing up for participation, after randomisation many of the coaches in the excluded clubs decided that the extra work would be too time consuming. Additionally, the disappointment of being randomised to the control group and hence not receiving the warm-up programme might explain the somewhat higher number of clubs we had to exclude from the control group. We think it is unlikely that the excluded clubs had coaches who were less "safety conscious" than the coaches in the clubs that completed the study. Our experience with this and several other studies is that, at the outset, few coaches consider injuries as a factor they can influence.

With respect to the internal validity, we found no differences between the two groups in their training or match exposure during the study. The coaches in both groups reported injuries and individual training and match participation prospectively on weekly registration forms according to pre-specified protocols and accepted injury definitions.[24] Because we recorded individual exposure we could adjust for playing time, which can vary greatly among players. This adjustment might be important as the best players play more games than substitutes and they might also train more. Individual exposure also takes censorship into account, such as abbreviated lengths of follow-up for reasons other than injury (such as illness, moving, quitting the sport).[26] Another advantage of this approach is that it provides accurate data about each player's exposure to the intervention, in this case the injury prevention programme.

Injury recorders, who were blinded to group allocation, interviewed the injured players using a standardised injury questionnaire as soon as possible after the weekly registration form was received. Even so, some coaches might have overlooked injuries, although this is less likely for more severe injuries such as knee and ankle sprains. Our definition of reportable injury embraced any injury that occurred during a scheduled match or training session, causing the player to be unable to fully take part in the next match or training session.[24] Given the individual activity logs kept by the coaches, it is therefore unlikely that injuries would go unreported, and we see no reason to expect a reporting bias between the groups. Our method should ensure good reliability and validity of the injury and exposure data.

The intention to treat analysis showed that the inflation factor for cluster effects was higher than our power calculation (2.7 *v* 1.8). We estimated the inflation factor on the incidence of lower extremity injuries in our previous study on a similar sample.[22] Yet our results indicate that we might have underestimated the number of players we needed to establish possible intervention effects. This is also supported by the larger confidence intervals of the rate ratios calculated from the Cox regression analysis (taking cluster randomisation into account) than the simpler Poisson regression model (assuming constant hazard per group). In addition, our power calculation was based on a dropout rate of 15% when the actual dropout rate was 25.6%.

Compliance

In our previous intervention study we tested the effect of a training programme,[21] in a similar cohort of young female footballers.[22] We were encouraged that compliance in the current trial was higher than with the previous programme (77% *v* 52%). One key objective for the revision was to improve the compliance among coaches and players, and, with this in mind, the revised programme was expanded with more exercises to provide variation and progression. It also included a new set of structured running exercises to make it better suited as a stand alone warm-up programme for training and matches. In addition, the first part of the programme included exercises with a partner, which seemed to appeal to the players.

The resources used to promote the programme among the intervention teams were moderate so it should be possible to replicate implementation in large scale nationwide programmes. The coaches and team captains were introduced to the programme during one three hour training session. To boost compliance we also developed new information material for coaches and players: a DVD showing all the exercises, a poster, a loose leaf exercise book, and small exercise cards attached to a handy neck strap that the coaches could bring to the training field. It was up to the coaches and team captains, however, to teach the programme to the players on the roster. Furthermore, the clubs received no follow-up visits throughout the season to refresh coaching skills or give players feedback on their performance. Despite the moderate efforts to promote the programme, compliance was good and we saw effects on the risk of injury. It should be possible to implement the programme at the community level by including injury prevention as part of basic coaching education and making educational material such as that developed for the current study available to teams, coaches, players, and parents.

The technical nature of many of the exercises in the programme required players to focus during training to gain the intended benefit. Site visits indicated that not all of the players seemed to concentrate fully on the performance of the exercises, which might be expected for this age group. Furthermore, the compliance logs documented that not all clubs completed the requested minimum of two training sessions a week. We included all clubs and players in the intention to treat analysis, which means that the preventive effect of the programme might be higher than reported. This is supported by subgroup analyses within the intervention group, indicating a trend towards a lower risk of injury among the most compliant players.

Structured programme of warm-up exercises to prevent injuries

The programme was developed on the basis of "The 11" programme[21] and the prevent injury and enhance performance (PEP) programme,[20] combined with running activities at the start and the end.[27] The running exercises were chosen not just to make the programme more suitable as a warm up but also to teach proper knee control and core stability during cutting and landing. Furthermore, the revised exercises include both variety and progression of difficulty. These elements were absent from the previously tested training programme[22] but exist in other successful prevention programmes.[27-30]

The focus on core stability, balance, and neuromuscular control as well as hip control and knee alignment that avoids excessive knee valgus during both static and dynamic movements is a feature of earlier intervention studies.[18 20 27-29 31] This rationale is justified by data from studies on the mechanisms of anterior cruciate ligament injuries.[32-36] These studies indicate that players could benefit from not allowing the knee to sag medially during football specific movements, when suddenly changing speed, or when being tackled by opponents. The programme therefore focused on proper biomechanical technique and improved awareness and control during standing, running, planting, cutting, jumping, and landing.

The programme included a set of balance exercises, and during single leg balance training the players were also purposely pushed off balance; this provided an

Table 3 | Most commonly injured body parts and most common type of acute and overuse injuries in young female footballers according to use of warm-up exercise programme (intervention). Values are numbers (percentages) of injuries unless otherwise indicated. Incidence is reported as number of injuries per 1000 player hours, with standard errors

	Intervention group (n=1055)		Control group (n=837)		Rate ratio (95% CI)*	P value (z test)
	Injuries	Incidence	Injuries	Incidence		
Body category:						
Knee	35 (21.7)	0.7 (0.1)	58 (27.0)	1.3 (0.2)	0.55 (0.36 to 0.84)	0.005
Ankle	51 (31.7)	1.0 (0.1)	52 (24.2)	1.1 (0.2)	0.89 (0.61 to 1.31)	0.562
Leg	14 (8.7)	0.3 (0.1)	22 (10.2)	0.5 (0.1)	0.58 (0.30 to 1.13)	0.111
Anterior thigh	9 (5.6)	0.2 (0.1)	9 (4.2)	0.2 (0.1)	0.91 (0.36 to 2.29)	0.842
Posterior thigh (hamstring)	5 (3.1)	0.1 (0.0)	8 (3.7)	0.2 (0.1)	0.57 (0.18 to 1.74)	0.322
Hip/groin	10 (6.2)	0.2 (0.1)	9 (4.2)	0.2 (0.1)	1.01 (0.41 to 2.49)	0.984
Acute injuries:						
Sprains	65 (47.8)	1.3 (0.2)	76 (46.6)	1.7 (0.2)	0.78 (0.56 to 1.08)	0.139
Strains	25 (18.4)	0.5 (0.1)	28 (17.2)	0.6 (0.1)	0.81 (0.47 to 1.39)	0.453
Contusions	16 (11.8)	0.3 (0.1)	33 (20.2)	0.7 (0.1)	0.44 (0.24 to 0.80)	0.007
Fractures	14 (10.3)	0.3 (0.1)	7 (4.3)	0.2 (0.1)	1.82 (0.74 to 4.51)	0.194
Overuse injuries:						
Lower extremity tendon pain	11 (44.0)	0.2 (0.1)	21 (40.4)	0.5 (0.1)	0.48 (0.23 to 0.99)	0.047
Low back pain	1 (3.4)	0.0 (0.0)	8 (14.3)	0.2 (0.0)	0.11 (0.01 to 0.91)	0.040
Anterior lower leg pain (periostitis)	9 (36.0)	0.2 (0.1)	12 (23.1)	0.3 (0.1)	0.68 (0.29 to 1.62)	0.384

*Rate ratio obtained from Poisson model.

additional challenge to the ability to maintain a stable core and proper alignment. Previous studies in footballers have shown that the rate of anterior cruciate ligament injuries can be reduced by improving dynamic and static balance, neuromuscular control, and proprioception.[20 28] Our programme also included strength exercises, such as the "Nordic hamstring lower," which has been shown to increase eccentric hamstring muscle strength[37] and decrease the rate of hamstring strain injuries.[38] The hamstrings can act as agonists to the anterior cruciate ligament during stop and jump tasks,[39-41] at least at knee flexion angles above 30°.[42-44] Stronger hamstring muscles might therefore prevent injuries to the ligament, but this theory has never been tested directly. Based on data from volleyball[39 45] and team handball,[27 29] we also encouraged players to reduce the impact of landings with increased hip and knee flexion and to land on two legs rather than one.

Our prevention programme is multifaceted and addresses many factors that could be related to the risk of injury (jogging and active stretching for general warm up, strength, balance, awareness of vulnerable hip and knee positions, technique of planting, cutting, landing, and running), and it is not possible to determine exactly which exercises or factors might have been responsible for the observed effects. Further studies are needed to determine what the key components are so that future programmes might require less time and effort.

Table 4 | Numbers and severity of injuries in young female footballers according to use of warm-up exercise programme (intervention)

	Intervention (n=1055)	Control (n=837)	Rate ratio (95% CI)*	P value (z test)
All injuries:				
Total	161	215	0.68 (0.56 to 0.84)	0.0003
Match	109	138	0.71 (0.55 to 0.91)	0.007
Training	51	74	0.63 (0.44 to 0.90)	0.012
Minimal injuries (1-3 days)	27	32	0.77 (0.46 to 1.28)	0.313
Mild injuries (4-7 days)	24	34	0.64 (0.38 to 1.08)	0.097
Moderate injuries (8-28 days)	63	70	0.82 (0.58 to 1.15)	0.250
Severe injuries (>28 days)	47	79	0.54 (0.38 to 0.78)	0.0009
Overuse injuries:				
Total	25	52	0.44 (0.27 to 0.71)	0.0007
Minimal injuries	5	10	0.46 (0.16 to 1.33)	0.142
Mild injuries	3	7	0.39 (0.10 to 1.51)	0.174
Moderate injuries	9	11	0.75 (0.31 to 1.80)	0.509
Severe injuries	8	24	0.30 (0.14 to 0.68)	0.004
Acute injuries:				
Total	136	163	0.76 (0.61 to 0.95)	0.017
Minimal injuries	22	22	0.91 (0.50 to 1.64)	0.757
Mild injuries	21	27	0.71 (0.40 to 1.25)	0.234
Moderate injuries	54	59	0.83 (0.58 to 1.21)	0.332
Severe injuries	39	55	0.65 (0.43 to 0.97)	0.037
Contact	53	76	0.64 (0.45 to 0.90)	0.011
Non-contact	55	58	0.86 (0.60 to 1.25)	0.435
Acute knee injuries	27	37	0.66 (0.41 to 1.09)	0.105
Acute ankle injuries	51	52	0.89 (0.61 to 1.31)	0.562

*Rate ratio obtained from Poisson model.

WHAT IS ALREADY KNOWN ON THIS TOPIC

The injury rate among female footballers, regardless of age and level of performance, approaches that of men

The risk of severe knee injuries, such as anterior cruciate ligament injuries, is three to five times higher for female than male football players

Studies from other sports indicate that it might be possible to reduce the rate of lower extremity injuries, but no programmes have been validated for female footballers

WHAT THIS STUDY ADDS

A comprehensive warm-up programme designed to improve strength, awareness, and neuromuscular control can prevent injuries in young female footballers

The risk of injury can be reduced by about one third and the risk of severe injuries by as much as a half

Except for a few reports from coaches on muscular soreness in the beginning of the intervention period and one report about a minor hamstring strain, we observed no negative effects of the programme.

Implications

We used young female footballers (aged 13-17) as a model, and we do not know if the results can be generalised to both sexes, other age groups, or other youth sports. Similar preventive programmes, however, were effective in senior elite football,[28 38] young male footballers,[46] and in both sexes in other sports.[30 31] Furthermore, in youth team handball Olsen et al[27] also documented a substantial decrease in the rate of injuries as a result of a similar structured warm-up programme. Football differs from many other team sports, however, in that there is a much higher potential for direct contact to the lower extremities. Nevertheless, the mechanisms for serious knee injuries seem to be comparable across many sports (mostly non-contact, resulting from pivoting and landing movements). It therefore seems reasonable to assume that the programme we used could be modified for use in other similar sports, at least for some types of injury.

One of the goals in sports injury prevention should be to develop less vulnerable movement patterns. Thus, it might be easier to work with even younger players who have not yet established their basic motion patterns. We therefore suggest that programmes to improve strength, awareness, and neuromuscular control of static and dynamic movements should be implemented as soon as children start playing organised football.

We thank the project assistants (Birgitte Lauersen, Agnethe Nilstad, Ellen Blom, Olav Kristianslund, Tone Wigemyr, Monika Bayer, Heidi M Pedersen, Vegar Vallestad, and John Bjørneboe), the coaches, and the players who participated in this study. A poster illustrating various exercise components and progressions of programme is available at www.ostrc.no/en/Project/144—The-11-plus/. Also, videos displaying every exercise in the programme (with Norwegian text and narrator) are available at www.klokavskade.no/no/Skadefri/Fotball/SPILLEKLAR/.

Contributors: TS, GM, KS, HS, MB, AJ, JD, RB, and TEA contributed to study conception, design, and development of the intervention. TS coordinated the study and managed all aspects of the trial, including data collection. IH conducted and initialised the data analyses, which were planned and checked with TS, RB, and TEA. TS, RB, and TEA wrote the first draft of the paper, and all authors contributed to the final manuscript. TS and TEA are guarantors.

Funding: This study was supported by grants from the FIFA Medical Assessment and Research Centre. The Oslo Sports Trauma Research Center has been established at the Norwegian School of Sport Sciences through grants from the Royal Norwegian Ministry of Culture and Church Affairs, the South-Eastern Norway Regional Health Authority, the Norwegian Olympic Committee and Confederation of Sport, and Norsk Tipping AS. No author or related institution has received any financial benefit from research in this study.

Competing interests: None declared.

Ethical approval: The study was approved by the regional committee for medical research ethics, South-Eastern Norway Regional Health Authority, Norway. Players and parents gave individual written informed consent.

Provenance and peer review: Not commissioned; externally peer reviewed.

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Accepted: 26 September 2008

Paper II

EDITOR'S CHOICE

Compliance with a comprehensive warm-up programme to prevent injuries in youth football

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Accepted 5 April 2010
Published Online First 15 June 2010

ABSTRACT

Background Participants' compliance, attitudes and beliefs have the potential to influence the efficacy of an intervention greatly.

Objective To characterise team and player compliance with a comprehensive injury prevention warm-up programme for football (The 11+), and to assess attitudes towards injury prevention among coaches and their association with compliance and injury risk.

Study Design A prospective cohort study and retrospective survey based on a cluster-randomised controlled trial with teams as the unit of randomisation.

Methods Compliance, exposure and injuries were registered prospectively in 65 of 125 football teams (1055 of 1892 female Norwegian players aged 13–17 years and 65 of 125 coaches) throughout one football season (March–October 2007). Standardised telephone interviews were conducted to assess coaches' attitudes towards injury prevention.

Results Teams completed the injury prevention programme in 77% (mean 1.3 sessions per week) of all training and match sessions, and players in 79% (mean 0.8 sessions per week) of the sessions they attended. Compared with players with intermediate compliance, players with high compliance with the programme had a 35% lower risk of all injuries (RR 0.65, 95% CI 0.46 to 0.91, p=0.011). Coaches who had previously utilised injury prevention training coached teams with a 46% lower risk of injury (OR 0.54, 95% CI 0.33 to 0.87, p=0.011).

Conclusions Compliance with the injury prevention programme was high, and players with high compliance had significantly lower injury risk than players with intermediate compliance. Positive attitudes towards injury prevention correlated with high compliance and lower injury risk.

Frameworks have been outlined to describe the systematic approach needed to build an evidence base for the prevention of sports injuries.[1–3] The effectiveness of an injury prevention programme depends, among other things, on uptake of the intervention among participants, that is, compliance. Therefore, to prevent injuries, it is crucial to understand the factors that influence athletes, coaches and sports administrators to accept, adopt and comply with the elements of the intervention.[2 3]

Documentation of participant compliance is often incomplete in studies examining the effectiveness of injury prevention protocols in team sports; the documentation of participant compliance is inconsistent. Whereas a number of studies have neglected compliance altogether,[4–12] some have noted the importance of compliance, but not reported it.[13–18] Others have reported compliance, but not linked it to an injury prevention effect estimate.[19–26] Finally, some studies have linked compliance to an effectiveness estimate.[27–32] We thus have limited data on the relationship between compliance and effectiveness.

Furthermore, when injury prevention measures are embedded into team training sessions, the compliance of the team is likely to depend greatly on the motivation, choices and actions of the head coach. We therefore determined to what degree an intervention is accepted and adopted by coaches. Recording individual participation, on the other hand, reveals the rate of uptake and actual usage of the intervention for each player. Recording team and player compliance together will provide detailed data on the overall compliance with the intervention (figure 1).

The primary aim of this study was to characterise the compliance of youth teams and players using an injury prevention training programme and to examine whether high compliance correlated with lower injury risk. We also wanted to identify coaches' attitudes towards injury prevention training and to examine whether their attitudes were associated with the compliance or the risk of injury within their teams.

METHODS

This study is based on data from a cluster-randomised controlled trial on young female footballers (soccer players) examining the injury preventive effect of a comprehensive warm-up programme (The 11+). The design, intervention programme and main results have been reported.[33]

Participants

Of the 181 teams organised in the girls' 15 and 16-year divisions in the south, east and middle regional districts of the Norwegian Football Association, 65 out of 125 teams entering the study were randomly assigned to the intervention group and formed the basis for the present paper (figure 2). To be included, teams had to carry out at least two training sessions per week, in addition to matches played. The competitive season lasted from the end of April until mid-October 2007, interrupted by a 7-week summer break. All teams were also followed for 2 months of preseason training (March–April). The recording of compliance included all the teams (n=65) in the intervention group, and the investigation

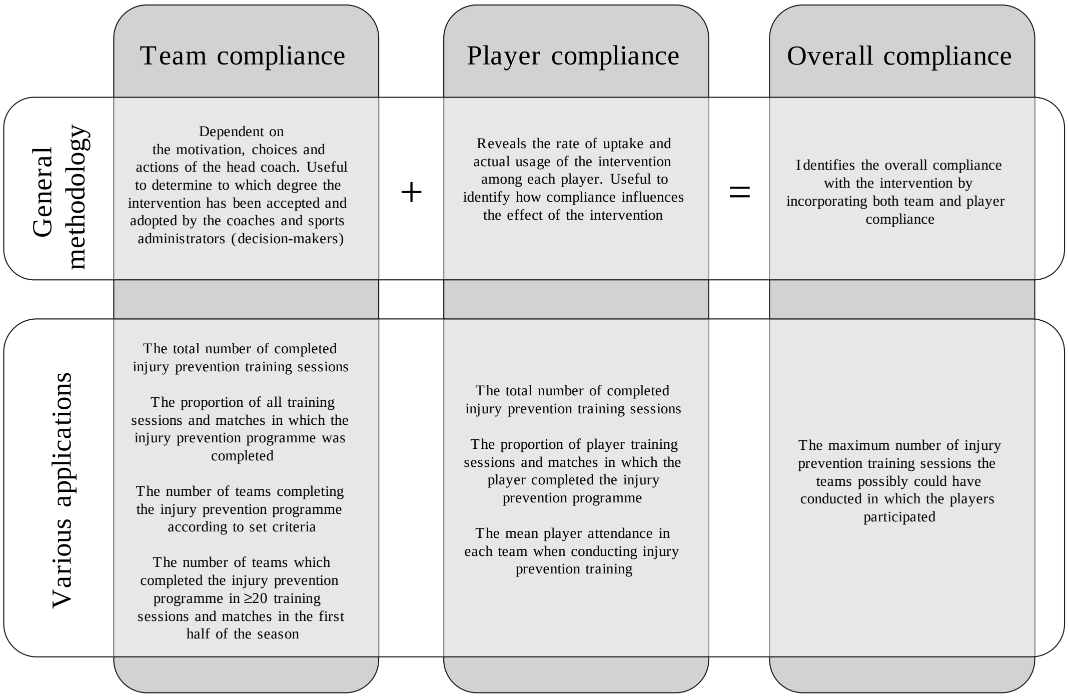

Figure 1 The distinction between compliance among teams and players, and definitions of compliance used in this study.

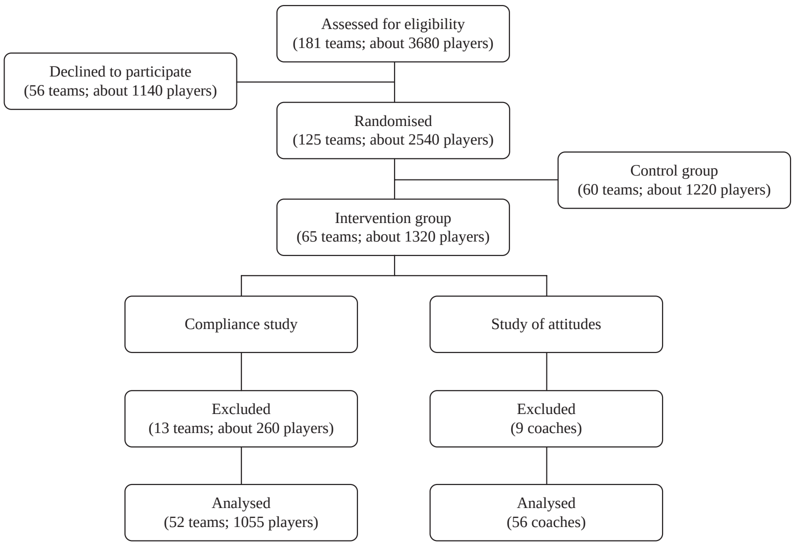

Figure 2 Flow of team clusters and players throughout the study.

of attitudes and beliefs towards injury prevention included all the coaches (n=65) of the intervention teams.

Compliance recording and reporting

The coaches reported injuries and individual player participation prospectively, as the number of minutes of exposure, for each training session and match on weekly registration forms throughout the study period. Furthermore, for each session the coaches quantitatively recorded whether the warm-up programme was carried out, as well as the participation of each player in the programme (yes/no). The registration forms were submitted by e-mail, mail, or fax to the Oslo

Br J Sports Med 2010;**44**:787–793. doi:10.1136/bjsm.2009.070672

Sports Trauma Research Center. Data on players who dropped out during the study period were included for the entire period of their participation. For comparison with results from previous studies compliance was defined and reported in multiple ways (figure 1).

Injury recording

One physical therapist and one medical student were given specific training on the protocols for injury classification and injury definitions (see Soligard *et al*)[33] before the start of the injury recording period. These injury recorders called every injured player to assess detailed aspects of the injury based on a standardised injury questionnaire,[34] and the players were in most cases reached within 4 weeks (range 1 day to 5 months) after the injury had occurred.

Study of attitudes and beliefs towards injury prevention

After the season, from mid-October to November, every coach in the intervention group was called to evaluate the complete warm-up programme and the exercises used, as well as to assess attitudes and beliefs towards injury prevention training in general. This retrospective study was based on a questionnaire designed by the authors, consisting of 28 closed and three open questions. The questionnaire was standardised using dichotomous or five-point Likert scale response alternatives in accordance with questionnaire design guidelines to ensure reliability and validity.[35] All interviews were conducted by a physical therapist (AN).

Statistical methods

This report is based on an exploratory post hoc analysis of data from the intervention group in a randomised controlled trial.[33] All statistical analyses were conducted using SPSS for Windows version 15.0 and STATA version 10.0. We used a Poisson regression model based on generalised estimating equations taking cluster effects into account as a per protocol analysis to compare the rate ratios (RR) of the risk of injury between teams as well as players (independent of club) stratified into tertiles of compliance according to the number of prevention sessions completed: low, intermediate and high. We used χ^2 tests to compare categorical variables between these subgroups and one-way analysis of variance to compare continuous variables. To investigate the relation between the coaches' attitudes and compliance with the warm-up programme, logistic regression analyses were used with compliance as the dependent variable. Attitudes among coaches who represented teams with high compliance were compared with attitudes among coaches from low-compliance teams. The teams who completed both the intervention study and the study of attitudes were included in this analysis. To investigate the relation between the coaches' attitudes and their teams' injury risk, logistic regression analyses were used with injury risk as the dependent variable. The results are presented as OR with 95% CI and p values. The summary measure of injury incidence (i) was calculated according to the formula $i=n/e$, where n is the number of injuries during the study period and e the sum of exposure time expressed in player hours of match, training or in total. Descriptive data for exposure, compliance with the warm-up programme, injury incidences and attitudes towards injury prevention training are presented as means with standard errors or 95% CI. RR are presented with 95% CI. Two tailed p values of 0.05 or less were regarded as significant.

RESULTS

Of the 65 teams in the intervention group, 52 (1055 players) completed the season and thus the compliance study. Fifty-six coaches completed the study of attitudes and beliefs towards injury prevention training; 50 belonged to teams that completed the compliance study, whereas six belonged to teams that dropped out during the season (figure 2).

Compliance of teams

The 52 teams completed the injury prevention programme in 2279 (mean 44±22 sessions, range 11–104) out of 2957 training sessions and matches throughout the season (77%), corresponding to 1.3 times per week. Of all the teams, 60% (n=31) completed the injury prevention programme two times per week or more in accordance with the recommendation. In all tertiles of compliance, the majority of the injury prevention sessions were conducted in the first half of the season (March–June). In this period the programme was completed in 82% of all sessions, whereas 75% of the teams (n=39) completed the prevention programme in 20 or more sessions (table 1). In the second part of the season (August–October) the programme was completed in 58% of all sessions. The difference in compliance between the first and the second part of the season was particularly noticeable in the tertile with low compliance; these teams completed the injury prevention programme seven times more often in the first part of the season. In the second half of the season the teams in the lowest tertile completed the programme in 2.4±4.1 sessions over a period of 11 weeks.

Compliance of players

The 1055 players completed the injury prevention programme in 28 212 (mean 27±19 sessions, range 0–95) out of 35 589 sessions throughout the season (79%), corresponding to 0.8 sessions per week. However, for each session the average number of players per team that participated in the injury prevention programme was 12.0, corresponding to only 59% of all players on the roster (mean 20.3 per team). As the team compliance was 77%, all the enrolled players therefore completed the injury prevention programme in 47% of the maximum number of sessions the teams possibly could have conducted.

The tertile of players with high compliance completed the injury prevention programme more than six times as often as players in the tertile with lowest compliance (table 1).

Compliance and injury risk

There was no difference in the risk of injury between teams with high, intermediate and low compliance (table 2). However, the risk of injury was 35% (p=0.011) lower among players in the tertile with the highest compliance (mean 49.2 sessions per season, 1.5 sessions per week; range 33–95 sessions per season) compared with players in the intermediate tertile (mean 23.4 sessions per season, 0.7 sessions per week; range 15–32 sessions per season). In contrast, there was no significant reduction (p=0.13) of injury risk between the intermediate tertile and the tertile with the lowest compliance (mean 7.7 sessions per season, 0.2 sessions per week; range 0–14 sessions). Furthermore, the risk of an acute injury was 39% (p=0.008) lower for players in the tertile with the highest compliance compared with players in the intermediate tertile, whereas a 35% reduction of injury risk compared with the tertile with the lowest compliance was not statistically significant (p=0.09).

Table 1 Team and player compliance with the injury prevention programme stratified into tertiles of compliance

	High compliance (n=17 teams/352 players)		Intermediate compliance (n=18 teams/351 players)		Low compliance (n=17 teams/352 players)		Total (n=52 teams/ 1055 players)	
	Mean±SD	Range	Mean±SD	Range	Mean±SD	Range	Mean±SD	Range
Teams								
First half of the season	43.4±9.2	34–66	28.3±6.2	18–36	18.7±7.0	4–28	30.1±12.6	4–66
Second half of the season	19.8±7.8	9–40	13.1±6.0	0–22	2.4±4.1	0–12	11.8±9.4	0–40
The whole season	68.6±14.8	52–104	42.3±5.8	30–52	20.6±5.6	11–28	43.8±21.8	11–104
Players								
The whole season	49.2±13.9	33–95	23.4±4.9	15–33	7.7±4.7	0–15	26.7±19.3	0–95

Values are mean numbers of injury prevention sessions completed in the different periods of the season, presented with SD and ranges.

Table 2 Injury risk among teams and players stratified into high, intermediate and low compliance

	Teams			Players		
	Injury incidence	Rate ratio	p Value	Injury incidence	Rate ratio	p Value
All injuries						
High compliance	3.1 (2.5–3.8)	–	–	2.6 (2.0–3.2)	–	–
Intermediate compliance	3.7 (2.8–4.7)	0.84 (0.59–1.78)	0.30	4.0 (3.0–5.0)	0.65 (0.46–0.91)	0.011
Low compliance	2.7 (1.6–3.7)	1.17 (0.75–1.85)	0.49	3.7 (2.2–5.3)	0.68 (0.41–1.12)	0.13
Acute injuries						
High compliance	2.5 (1.9–3.1)	–	–	2.1 (1.6–2.6)	–	–
Intermediate compliance	3.4 (2.5–4.3)	0.73 (0.50–1.05)	0.09	3.5 (2.5–4.4)	0.61 (0.42–0.88)	0.008
Low compliance	2.3 (1.3–3.3)	1.06 (0.65–1.74)	0.81	3.3 (1.8–4.7)	0.65 (0.39–1.08)	0.09

High compliance tertile is reference group.

Coach attitudes, compliance and injury risk

All the coaches (n=56) expressed that including injury prevention training in the training programme is important; 80% (n=45) stated that it is 'very important' and 20% (n=11) that it is 'important'. Regarding the perceived risk of sustaining an injury, 29% (n=16) of the coaches believed that their players were at high risk, 59% (n=33) believed that the risk of injury was intermediate and 13% (n=7) believed that the risk was low. However, 54% (n=30) of the coaches had never previously conducted injury prevention training. According to 75% (n=42) of the coaches, the media and profiled athletes largely influence their motivation to carry out injury prevention training. The majority of the coaches believed that the motivation of the coach is significant when trying to motivate young female football players to do injury prevention training (95%, n=53).

Of the coaches from teams with high compliance, 94% (n=16) believed that the players' motivation to complete the injury prevention programme was high, as opposed to 41% (n=7) of the coaches from low-compliance teams. The probability of having low compliance with the injury prevention programme was 87% higher if the coach believed that the programme was too time-consuming (OR 0.13, 95% CI 0.03 to 0.60, p=0.009). The opinion that this injury prevention programme did not include enough football-specific activities resulted in an 81% higher probability of low compliance with the programme (OR 0.19, 95% CI 0.40 to 0.92, p=0.038). Whether the coach had previously utilised injury prevention training in a similar group of players did not influence the compliance with the injury prevention programme (OR 0.60, 95% CI 0.14 to 2.47, p=0.47).

There was no significant relationship between the injury risk of the teams and the overall attitude towards injury prevention training among their coaches (p=0.33). However, compared with teams with coaches who had never undertaken injury prevention training before, teams with coaches who had used such training previously had 46% fewer injuries (OR 0.54, 95% CI 0.33 to 0.87, p=0.011).

DISCUSSION

In this study, compliance was good; teams used the injury prevention programme in 77% of all training sessions and matches and players completed the programme in 79% of the sessions they attended. Also, the risk of overall and acute injuries was reduced by more than a third among players with high compliance compared with players with intermediate compliance.

Compliance and risk of injury

The players with high compliance completed twice as many injury prevention sessions as the players with intermediate compliance (1.5 vs 0.7 sessions per week). Interestingly, the preventive effect of The 11+ therefore increased with the rate of use, at least when conducted more than 1.5 times per week on average. No studies have similarly compared the risk of injury in players and teams with high, intermediate and low compliance with an intervention to prevent injuries. However, similar indications of exposure–response relationships have been found previously.[28] Furthermore, a post hoc analysis showed that compared with the controls,[33] players with high compliance experienced a 45% reduction in the overall risk of injury (data not shown), that is, an even greater effect than when compared with intervention players with intermediate and low compliance.

Overall, the intervention players completed 0.8 injury prevention sessions each week on average, less than the recommendation of at least two sessions per week. However, they still experienced a 30–50% reduction in the risk of various injuries compared with the controls. This indicates that the injury prevention programme achieved the desired injury preventive effect.

In contrast to the findings among players, we found no significant differences in the overall or acute risk of injuries between teams with different levels of compliance. This is explained by the large variations in compliance among the players within each team; the players with high compliance had a sixfold higher use of the programme compared with the players with low compliance. These findings emphasise the inadequacy of recording compliance on a team basis only. The overall compliance is a product of the compliance among the teams and the player participation rate (figure 1). Although the compliance among teams and attending players was good, certain players in each team rarely took part in the team activities, despite being registered on the roster at the start of the season. Therefore, the whole group of enrolled players completed the injury prevention programme in 47% of the maximum number of sessions the teams possibly could have conducted.

It should be noted that the teams with low compliance reported three times lower exposure to football than the teams with high compliance, and four of 10 teams with low compliance did not report any injuries at all. Even though calculations of injury incidence take exposure into account, a minimum exposure is necessary to be at risk of injury. Moreover, coaches less thorough in conducting the injury prevention programme and recording compliance may also have been less likely to record injuries. If so, the injury incidence in the low compliance group may have been underestimated somewhat.

The programme was designed to prevent injuries. However, to make it attractive for coaches and players, The 11+ was specifically tailored to football players and we included elements of variation and progression in the exercise prescription. We also focused on organising streamlined and efficient 3 h educational meetings at baseline, at which the coaches were provided with a selection of material detailing the exercises. Although we gave a set of footballs to the teams that completed the collection of injuries and exposure, no incentives were provided to ensure high compliance by coaches and players other than telephone and e-mail contacts related to data collection. Indeed, the compliance rates among teams in the current study was higher than previously reported among teams,[18 21 24 27 28 31] as well as among players.[23 29 30] In addition, our intervention period lasted longer than comparable interventions in other studies. Although compliance decreased from the first to the second half of the season, these findings may imply that a long-term intervention period is not synonymous with low motivation and compliance among the participants. Other factors, such as the content, the relevance, the availability and the perceived difficulty of the intervention may also play an important role.

Attitudes towards injury prevention training

Compliance with an intervention depends upon the motivation among the participants to perform a certain safety behaviour and that the barriers associated with the behaviour are limited.[2] The strongest motivator for the coach was the expectation of fewer injuries. All coaches emphasised the importance of including injury prevention training in training, and the majority believed that the risk of injury among their players was high or intermediate. Nonetheless, more than half of the coaches had never previously conducted injury prevention training; this suggests that previous barriers associated with such training were too high.

The 11+ was completed in 20 min once the players were familiar with the programme. In addition to providing players with a solid warm-up, the programme included exercises aimed at improving strength, core stability, plyometrics and balance, components that presumably would be beneficial both in preventing injuries and enhancing performance. Nevertheless, time constraints were perceived as a barrier by many of the coaches. Moreover, if the coach held the opinion that the programme did not include enough football-specific activities, the probability of low compliance increased by 81%. This indicates that content is important when implementing injury prevention measures in the sports community. The finding corresponds with theories proposing that when the barriers associated with a task are perceived as great, the task is less likely to be carried out.[36 37]

All coaches believed that their attitudes towards injury prevention training influenced their players' motivation to perform the programme—they served as role models. Furthermore, the majority of coaches responded that the media and high-profile athletes influence the motivation to carry out injury prevention training. These findings are supported by well-founded theories suggesting that if people think their significant others want them to perform a behaviour, this results in a higher motivation and greater likelihood of action.[36 38]

Interestingly, injuries were half as likely in the teams of the coaches who previously in their coaching career had undertaken injury prevention training compared with teams of coaches who had not used such training. Previous experience with injury prevention training seems to improve the positive attitudes of coaches and may increase the implementation of The 11+ in both training sessions and before matches.

General methodological considerations

A strength of the study is that the compliance was recorded both among teams and individual players, providing a detailed account of the acceptance of the intervention. In addition, the sample size of both players and coaches was large and the follow-up period was one complete football season. With respect to the coach interviews, the main objective was to identify the attitudes and beliefs towards injury prevention training among the coaches, but we also wanted to evaluate the warm-up programme and its exercises. As a consequence, the interviews were conducted after the season. However, the perceived risk of injury can easily influence the attitudes towards injury prevention training;[36 39] thus, it would have been more appropriate to assess attitudes before the season and to evaluate the content of the programme after the season.

Regarding the relationship between coach attitudes, compliance and team injury risk, only coaches who completed the recording of compliance and injuries were included in the analyses. Although the most common barrier to study participation reported by coaches was the additional work of data recording and reporting, some teams may have dropped out due to low motivation towards the intervention programme. Therefore, coach attitudes to the programme may be less favourable than those reported by the study participants.

Except for a 3 h instructional course with the coaches and team captains in the preseason, the teams received no follow-up visits to refresh coaching skills or give players feedback on their performance. Throughout the season it was up to the coaches to make sure the exercises were performed properly with high quality. Although the programme proved to reduce the risk of several injury types, follow-up visits during the season could have proved helpful in ensuring the quality of the exercise performance and might possibly have resulted in an even higher preventive effect.

The coach of each team recorded the injuries, the exposure and the compliance. We did not monitor the validity and reliability of their recordings. In cases in which the registration form was not completed during or immediately after a training session or match the coach had to complete the registration form in a retrospective manner. However, recall bias is presumably small, because the majority of the coaches followed the protocol and submitted their registration forms on a weekly basis. Also, all teams were offered an incentive, provided they recorded all data throughout the study period. It is possible that coaches completed and submitted the registration forms merely to receive the reward, without ensuring the accuracy of the recorded data. This may have impaired the reliability of the submitted data.

Implications

Knowledge of factors that influence compliance with an intervention is still limited. This study is one of few that have aimed to identify these factors. The findings demonstrated that attitudes towards injury prevention training are associated with the rate of uptake of an intervention. Attitudes are developed from an early age. It may be important to implement injury prevention training as soon as children start participating in organised sports to make it a natural part of their training routines. It is also necessary to increase the understanding of the benefits of injury prevention among coaches in both youth and elite sports. Injury prevention training thus ought to be a core element of coach education and training programmes in football and other sports.

When recording and reporting compliance in team sports there should be a distinction between compliance among teams and among individual players. The compliance of a team is highly dependent on the motivation, choices and actions of the head coach. Recording individual participation, on the other hand, reveals the rate of uptake and actual usage of the intervention for each player. The recording of individual compliance is thus necessary to investigate how compliance influences the effect of an intervention and to identify possible exposure–response relationships. Recording team and player compliance together will provide detailed data on the overall compliance with the intervention (figure 1), and such methods should be applied in future research.

CONCLUSION

The compliance among players and teams with The 11+ injury prevention programme was high. The risk of overall and acute injuries was reduced by more than a third among players with high compliance. Positive coach attitudes correlated with high compliance and lower injury risk.

Acknowledgements The authors would like to thank the project assistants (Birgitte Lauersen, Ellen Blom, Olav Kristianslund and Tone Wigemyr), the coaches and the players who participated in this study.

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

Competing interests None.

Patient consent Obtained.

Ethics approval This study was conducted with the approval of the Regional Committee for Medical Research Ethics, South-Eastern Norway Regional Health Authority, Norway.

Provenance and peer review Not commissioned; externally peer reviewed.

What is already known on this topic

- The effectiveness of an injury prevention programme depends, among other things, on uptake of the intervention among participants, that is, compliance.
- Knowledge about the relationship between compliance and injury prevention effectiveness is limited.

What this study adds

- When embedding injury prevention into team training sessions, recording both team and player compliance is necessary to document overall compliance and exposure–response relationships.
- Players with high compliance appear to benefit in terms of fewer injuries.
- Positive coach attitudes are associated with high compliance and lower injury risk.

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Paper III

Are skilled players at greater risk of injury in female youth football?

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Accepted 5 September 2010
Published Online First 3 November 2010

ABSTRACT

Background Knowledge of skill-related risk factors for injury in football is limited.

Objective To investigate whether there is an association between football skills and risk of injury in football.

Study Design Prospective cohort study of the incidence of injuries and a retrospective evaluation of the players' skill-level.

Methods Exposure and injuries were registered prospectively in 82 of 125 football teams (1665 of 2540 female Norwegian amateur players aged 13–17 years) throughout one football season (March–October 2007). A standardised questionnaire designed to assess the football skills of each player was completed by the coaches after the season.

Results Across the different skill attributes, the injury incidence in the high-skilled players varied from 4.4 to 4.9 injuries per 1000 player hours, compared to 2.8 to 4.0 injuries per 1000 player hours in the low-skilled players. Players skilled at ball receiving, passing and shooting, heading, tackling, decision-making when in ball possession or in defence and physically strong players were at significantly greater risk of sustaining any injury, an acute injury and a contact injury than their less skilled teammates (rate ratio: 1.50–3.19, all $p<0.05$).

Conclusions Players with high levels of football skill were at greater risk of sustaining injuries than their less skilled teammates.

INTRODUCTION

The number of female youth footballers (soccer players) has increased rapidly during the last decade, and there are already more than 2.9 million registered players worldwide.[1] Young female players incur from 8.3 to 22.4 injuries per 1000 match hours and from 1.1 to 4.6 injuries per 1000 training hours,[2–5] and acute, lower extremity injuries dominate. Players with a history of previous injury have an increased risk of recurrences,[3 6] perhaps because they return too early and without sufficient rehabilitation. Furthermore, debilitating long-term health consequences have been reported after ankle and knee sprains.[7 8] As injuries can cause early retirement and limit future physical activity, it has also been argued that they may have an additional negative effect on future health.[9]

Injuries can to a great extent be reduced by taking significant risk factors into consideration and implementing injury prevention strategies.[10 11] Still, a general trend in football is that little is done to minimise injuries, while technical, tactical and physiological skills are honed carefully.[12] This is somewhat counterintuitive, as football performance is highly dependent on remaining injury free.[13 14]

Although the relationship between the skill attributes underpinning performance in football and injury risk is largely unknown,[3 15–20] there are indications from male football that skilled players may be at greater risk of injury than their less skilled counterparts.[19 20] One suggestion is that skilled players are more likely to be in ball possession, and therefore are more exposed to tackles and other duels. In young female players, however, the only study available reported no association between the risk of injury and physiological attributes such as dynamic balance, vertical jump height or endurance.[3] Nonetheless, more documentation is needed, in particular regarding the influence of technical and tactical football skills, which to date remains unexplored in female youth football.

The aim of this study was to investigate whether there are any associations between technical, tactical and physiological skill attributes in football and risk of injury in young female players.

METHODS

This study is based on data from a cluster-randomised controlled trial on young female footballers examining the injury-preventive effect of a comprehensive warm-up programme (The 11+). The design, intervention programme and main results have been reported.[11] This investigation included a prospective registration of the incidence of injuries and a retrospective evaluation of the skill level of players.

The study was approved by the Regional Committee for Medical Research Ethics, South-Eastern Norway Regional Health Authority, Norway. Informed consent was obtained from the players and their parents.

Participants

Of the 181 teams organised in the girls' 15- and 16-year amateur leagues in the south, east and middle regional districts of the Norwegian Football Association, 125 teams entered the randomised controlled trial. To be included in the current study, however, teams were required to have recorded injuries and exposure for the complete 2007 season (figure 1).

Recording and reporting of injuries and exposure

The coaches reported injuries and individual player participation prospectively, on a weekly basis. One physical therapist and one medical student called every injured player to assess detailed aspects of the injury based on a standardised injury questionnaire.[21] These injury recorders were given specific training on the protocols for injury classification and injury definitions (table 1) before the start of the injury recording period.

Recording of football skills

A standardised questionnaire designed to assess the football skills of each individual player compared to the rest of the team was mailed or emailed to the coach of each team 2 months after the end of the season 2007. The coach completed one questionnaire for each player. The skill assessment included 12 technical, tactical and physiological attributes. The technical attributes comprised ball receiving, passing and shooting (precision, power), heading (power and timing), dribbling and tackling. The tactical attributes comprised decision-making when the player had ball possession, decision-making when the team, but not the player, had ball possession (offensive decisions), and decision-making when the opposing team had ball possession (defensive decisions). The physiological attributes comprised endurance, speed/agility, strength (football-specific strength) and coordination/balance. The coach categorised each player into four quartiles; weakest, below average, above average or best. This was done separately for each of the 12 skill attributes.

Statistical methods

The quartiles of skill-level were merged into two groups consisting of high- and low-skilled players. We used χ^2 tests to compare the distribution of players in these two groups for all 12 attributes with Bonferroni p values correction to 0.05/12 = 0.00417. Furthermore, we used χ^2 tests to examine whether there were any relationships between the players' skill-level across the 12 skill attributes. In each test the players were classified in terms of whether they were equally assessed in two skill attributes. This resulted in 66 tests with Bonferroni p values correction to 0.05/66 = 0.00076. Unpaired two-sample t tests were used to compare the match exposure time of the players with high and low skill in each attribute. To avoid bias related to absence from training and matches due to injury only uninjured players were included in this analysis. These analyses were conducted in SPSS (SPSS for Windows 15.0; SPSS, Chicago, Illinois, USA).

To estimate the relation between skill level and risk of injury we used a Cox regression model with the robust calculation method of the variance–covariance matrix,[23] taking the cluster randomisation by clubs into account. Rate ratios (RRs) were tested with Wald test. These analyses were conducted in STATA (STATA 10.0; Stata Corporation, Lakeway Drive, Texas, USA, 2007). Players in the low-skill group were used as the reference group. Interaction between group allocation (intervention or control) and skill level for each of the 12 attributes was tested with a z test, using the results from the Cox regression model with injuries overall as the dependent variable. No significant interaction was found (all p>0.20) and the two groups were merged. The injury incidence was calculated based on the number of injuries during the study period divided by the sum of exposure time expressed in player hours of match, training or in total. Descriptive data on players' injury incidence and skill-level were calculated by means with 95% CIs. Two tailed p values <0.05 were regarded as significant.

RESULTS

Of the 82 teams entering, 56 teams completed the study (68%, 1034 players). The overall exposure to football was 61 295 h (21 893 h of matches, 39 402 h of training). Two-hundred and two players sustained 259 injuries (167 match injuries, 89 training injuries). Of these, 203 (78%) were acute injuries and 56 (22%) overuse injuries. The majority of all injuries occurred to the lower extremity (n=219; 85%). In terms of injury mechanisms, there were 133 (51%) contact injuries and 115 (44%) non-contact injuries. For 11 (5%) of the injuries the mechanism was unknown.

The distribution of players rated as high skilled and low skilled was skewed (table 2); for 11 of 12 skill attributes a

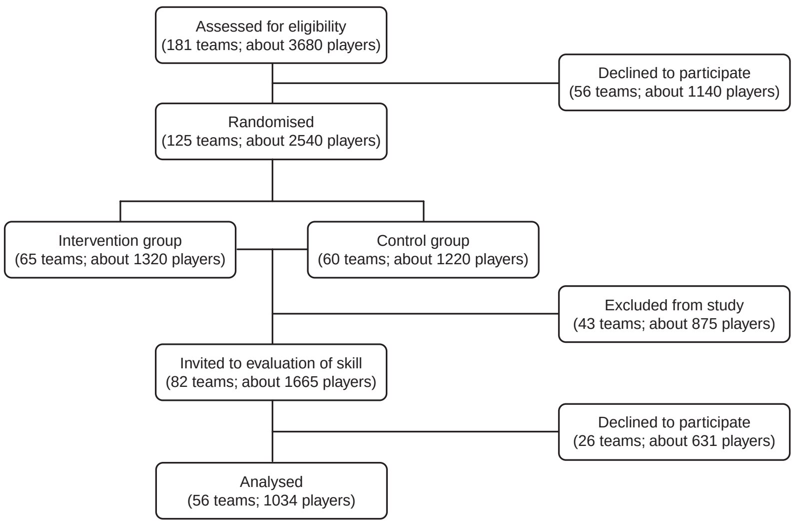

Figure 1 Flow of team clusters and players throughout the study.

majority (56–71%) was rated as highly skilled. There was a significant relationship between how the players were rated across all 12 attributes (all p<0.000001). Each player's level of skill in one attribute was in 63–84% of the cases identical to the same player's skill level in other attributes.

In all skill attributes the highly skilled players had significantly higher match exposure than players with low skill level (all p<0.00001). For all attributes, except speed/agility, the skilled players also had higher exposure to training (all p<0.001). In players who were assessed as highly skilled across all of the attributes (n=203) the average match exposure was 104% higher than in players with low skill level across all attributes (n=71; p<0.001).

Football skills and risk of injury

The injury incidence among highly skilled players varied from 4.4 to 4.9 injuries per 1000 player hours. By contrast, players with low skill level sustained 2.8–4.0 injuries per 1000 player hours. Table 3 shows the relative risk of injury in high-skilled players compared to low-skilled players.

The players with good ball-receiving technique were at greater risk of injuries overall, acute injuries and contact injuries than the players with poor receiving technique (table 3). Players who were highly skilled in passing and shooting, heading and tackling had significantly higher risk of injuries overall, injuries to the lower extremity, acute injuries and contact injuries than the players with low skill level in these attributes. Furthermore, players with good dribbling technique were at higher risk of contact injuries compared to players with poor dribbling technique.

Table 1 Operational definitions used in the recording of injury

Reportable injury[22]	An injury occurred during a scheduled match or training session, causing the player to be unable to fully take part in the next match or training session
Player	A player was entered into the study if she was registered by the coach on the club roster as participating for the club's team competing in the 15- or 16-year divisions
Return to participation	The player was defined as injured until she was fully fit to take part in all types of training and matches
Type of injury	Acute – injury with sudden onset associated with known trauma Overuse – injury with gradual onset without known trauma Contact – injury resulting from contact with another player Non-contact – injury occurring without contact with another player

The players who made good tactical decisions in defence experienced a significantly higher risk of all the tested injury outcomes compared to players who made poor defensive decisions. Correspondingly, players who made good decisions when in possession of the ball were at higher risk of injuries overall, injuries to the lower extremity, acute injuries and contact injuries than the players who displayed poor decision-making when in ball possession.

Regarding the physiological attributes, the most distinctive finding was that physically strong players experienced a higher risk of injuries overall, injuries to the lower extremity, acute injuries and contact injuries compared to physically weaker players.

DISCUSSION

The main finding of this cohort study was that the players with good football skills were at greater risk of injury than their less skilled teammates. In particular, the risk of sustaining contact injuries was high among skilled players. The increased injury risk was most evident in players with high technical and tactical skills and in physically strong players.

Football skills and risk of injury

The data on the relationship between football skills and risk of injury in football are equivocal.[3 15–20] In youth football, Emery *et al*[3] found no association between the risk of injury and the dynamic balance, vertical jump height, and endurance of female and male players 12–18 years of age. In male youth football, Le Gall *et al*[19] reported no difference in the overall risk of injury between players acquiring a professional contract and those who did not. Yet, a higher risk of moderate and major injuries was found in the non-professionals, while the professionals sustained more injuries to the lower extremity, contusions to the lower leg, minor injuries and re-injuries. The latter results are supported by Severino *et al*,[20] who in 11- to 12-year-old males found that injured players were better at ball juggling, dribbling, agility and anaerobic performance.

It is difficult to suggest reasons for the higher risk of injury in the skilled players compared with their less skilled teammates. Previously, it has been argued that technically skilled players may be less injury-prone due to their ability to efficiently control and pass the ball before being challenged by the opposing player.[24] Likewise, tactically skilled players

Table 2 Number of players (%) categorised as high skill and low skill

	Players with low skill	Players with high skill	Missing	p-Value
Technical attributes				
Ball receiving	413 (39.9%)	621 (60.1%)	–	<0.001
Passing and shooting (precision, power)	351 (33.9%)	683 (66.1%)	–	<0.001
Heading (timing, power)	531 (51.4%)	501 (48.5%)	1 (0.1%)	0.367
Dribbling	447 (43.2%)	582 (56.3%)	5 (0.5%)	<0.001
Tackling	351 (33.9%)	679 (65.7%)	4 (0.4%)	<0.001
Tactical attributes. Decision-making when				
in ball possession (offensive)	371 (35.9%)	662 (64.0%)	1 (0.1%)	<0.001
not in ball possession (offensive)	434 (42.0%)	592 (57.3%)	8 (0.8%)	<0.001
in defence	410 (39.7%)	612 (59.2%)	12 (1.2%)	<0.001
Physiological attributes				
Endurance	391 (37.8%)	643 (62.2%)	–	<0.001
Speed/agility	393 (38.0%)	639 (61.8%)	2 (0.2%)	<0.001
Strength (football specific strength)	313 (30.3%)	720 (69.6%)	1 (0.1%)	<0.001
Coordination/balance	300 (29.0%)	734 (71.0%)	–	<0.001

Table 3 Relative risk of injury in high-skilled players compared to low-skilled players

	Injuries overall	Lower extremity injuries	Acute injuries	Overuse injuries	Contact injuries	Non-contact injuries
Technical attributes						
Ball receiving	1.55 (1.04 to 2.31)*	1.48 (1.00 to 2.19)	1.64 (1.06 to 2.53)*	1.23 (0.68 to 2.25)	3.19 (1.91 to 5.32)**	0.96 (0.58 to 1.58)
Passing and shooting (precision, power)	1.82 (1.26 to 2.63)**	1.64 (1.13 to 2.38)**	1.99 (1.31 to 3.03)**	1.34 (0.72 to 2.49)	3.13 (1.83 to 5.35)**	1.10 (0.74 to 1.64)
Heading (timing, power)	1.50 (1.13 to 2.00)**	1.56 (1.14 to 2.14)**	1.53 (1.11 to 2.11)**	1.17 (0.62 to 2.21)	1.77 (1.25 to 2.50)**	1.24 (0.82 to 1.87)
Dribbling	1.27 (0.91 to 1.77)	1.32 (0.94 to 1.86)	1.23 (0.86 to 1.75)	1.61 (0.91 to 2.85)	2.10 (1.37 to 3.22)**	0.93 (0.59 to 1.46)
Tackling	1.70 (1.18 to 2.45)**	1.68 (1.13 to 2.49)*	1.83 (1.22 to 2.73)**	1.48 (0.73 to 3.00)	2.37 (1.42 to 3.97)**	1.18 (0.79 to 1.78)
Tactical attributes. Decision-making when						
in ball possession (offensive)	1.62 (1.08 to 2.45)*	1.55 (1.01 to 2.36)*	1.66 (1.03 to 2.67)*	1.29 (0.71 to 2.37)	3.12 (1.63 to 5.97)**	0.95 (0.62 to 1.45)
not in ball possession (offensive)	1.30 (0.92 to 1.85)	1.33 (0.93 to 1.91)	1.41 (0.98 to 2.03)	0.95 (0.53 to 1.73)	2.07 (1.34 to 3.20)**	0.93 (0.62 to 1.40)
in defence	1.81 (1.23 to 2.65)**	1.84 (1.20 to 2.84)**	1.79 (1.17 to 2.73)**	1.96 (1.02 to 3.78)*	1.95 (1.19 to 3.18)**	1.62 (1.01 to 2.61)*
Physiological attributes						
Endurance	1.18 (0.84 to 1.66)	1.28 (0.91 to 1.80)	1.21 (0.83 to 1.76)	1.09 (0.57 to 2.08)	1.45 (0.90 to 2.34)	0.89 (0.56 to 1.43)
Speed/agility	1.21 (0.90 to 1.61)	1.36 (1.00 to 1.85)*	1.22 (0.89 to 1.67)	1.02 (0.59 to 1.77)	1.24 (0.82 to 1.89)	1.12 (0.77 to 1.64)
Strength (football specific strength)	1.62 (1.18 to 2.22)**	1.57 (1.13 to 2.17)**	1.72 (1.22 to 2.44)**	1.46 (0.73 to 2.92)	2.15 (1.34 to 3.44)**	1.25 (0.86 to 1.82)
Coordination/balance	1.19 (0.79 to 1.79)	1.21 (0.79 to 1.86)	1.32 (0.88 to 1.99)	0.82 (0.42 to 1.59)	1.65 (1.04 to 2.63)*	0.92 (0.53 to 1.57)

Values are rate ratios with 95% CIs. Rate ratios calculated from Cox model according to method of Lin and Wei.[23]
*$p<0.05$, **$p<0.01$.

may be protected from injury, because they possess the ability to recognise potentially hazardous situations before they occur, and thus avoid them.[25] Although these theories intuitively seem valid, they do not account for the fact that skilled players have more ball possession and consequently are more exposed to tackles and other duels.[19 25 26] This rationale is reflected by our findings; players skilled in ball receiving, passing and shooting, and decision-making when in ball possession, experienced a threefold risk of contact injury. In our analyses, we have corrected for exposure, estimated as the number of hours of match and training exposure. In this way, the fact that skilled players are more likely to be selected for games has been adjusted for. However, highly skilled players are most likely also more involved in the game, more prone to tackles and foul play, and hence, at greater risk of injury than their less skilled counterparts. Although generally not feasible in youth football, notational analysis tools[27] provide the opportunity to record whether skilled players are more involved in game situations that entail a higher risk of injury, such as tackles.

Previously, it has been shown that the risk of injury in young female amateur players increases by 12% for every successive year of participation in organised football.[6] Moreover, previous injuries, as well as symptoms from previous injuries, make the player more susceptible to re-injuries.[3 6 28] Although these factors were not recorded in the current study, one possible scenario is that compared to their less skilled teammates, the skilled players not only played more football during the season but also started playing football at an earlier age. Furthermore, key players may experience higher external pressure or be more motivated to quickly return to play after an injury. Inadequate rehabilitation and premature return to play may increase the risk of exacerbations or re-injuries[29] and may thus lead to a higher injury risk in skilled players.

Methodological considerations

In this study exposure was recorded individually, and not on a team basis. Individual exposure takes censorship into account, such as abbreviated lengths of follow-up for reasons other than injury (eg, illness, moving, quitting the sport).[30] Furthermore, we adjusted the analyses for playing time which can vary greatly among players. The individual exposure demonstrated that the high-skilled players had a higher match and training exposure than their less skilled teammates. However, since match exposure was a dichotomous variable (participation yes/no), it remains possible that the low-skilled players not only played fewer matches but also were on the field for a lower proportion of the match. This may have lead to an overestimation of match exposure and an underestimation of injury risk among the low-skilled players.

Injury recorders, who were blinded to group allocation, interviewed the injured players based on a standardised injury questionnaire as soon as possible after the weekly registration form was received. Even so, there is a possibility that injuries may have been overlooked by the coaches. However, given the individual activity logs kept by the coaches and the time-loss injury definition,[22] we think it is unlikely that injuries would go unreported. Thus, our method should ensure good reliability and validity of the injury and exposure data.

The main limitation of the study is that the recording of skills was conducted retrospectively, 2 months after the recording of injuries was completed. This may add uncertainty as to whether a player's level of skill is a possible cause or a consequence of the injury,[30] and may be a limitation if the skill assessment of the coach was influenced by his/her knowledge of the player's injury status. However, we believe this to be unlikely, as the purpose of the assessment they were asked to make was not explicitly linked to the study purpose. There is also an obvious advantage of recording the level of skill retrospectively; it allows for an overall assessment of the players' performance throughout the course of a complete season. Nevertheless, skill is not a static variable and potential change in the different skill attributes of the players during the season was not accounted for. In future studies, it would be advisable to measure the skills before the injuries occur and follow-up with prospective repeated assessments throughout the season.

Another limitation is that the skill assessment approach was not validated. In future studies, the use of established tests for passing,[31 32] shooting,[32] dribbling[33] and physical performance[34–36] should be considered. Nevertheless, football is a complex sport where performance is determined by a wide range of technical, tactical and physiological skill attributes.

It is questionable whether performance in football can be assessed strictly using objective testing,[37] and the qualitative assessment of a coach can therefore be useful.

The majority of the coaches were volunteers such as parents and their level of education and experience as football coaches was not recorded. Different interpretations of the skill attributes may have affected the inter-rater reliability of the skill assessment. Furthermore, a test–retest procedure of the coaches' skill assessment would have been useful to evaluate the intra-rater reliability. However, 84% of the players were assessed equally in ball receiving and dribbling; two technical skill attributes assumed to be related. By contrast, only 63% of the players were assessed equally in the less-related skill attributes heading technique and speed/agility. This exemplifies our findings of a consistent logical relation between attributes, which strengthens the reliability of the coaches' skill assessment.

Half of the players performed an injury prevention programme throughout the study. The risk of injuries overall, overuse injuries and severe injuries was reduced in these players.[11] However, this did not bias the current results, as no interaction was found between the implementation of the injury prevention programme and the association between the players' level of skill and their injury risk.

Implications

Considering the limited knowledge about football skills as a potential injury risk factor in football, our findings need to be confirmed by subsequent studies in youth football, as well as in adult cohorts. Furthermore, by implementing actual game play measures (match statistics) in future research we can ascertain whether skilled players actually are more involved in game situations that entail a higher risk of injury. The disproportionate high risk of contact injuries in players who excel in youth football does in any case seem to warrant injury prevention to focus more on the injuries occurring from tackles and contact situations. Stricter interpretation of the fair play rules and better refereeing may be important means to protect the 'Messis' and 'Martas'[38] of tomorrow from career-ending injuries and allow them to hone their skills throughout adolescence to achieve their optimal potential in adulthood. Previously proposed measures to prevent contact injuries include modification and enforcement of the Laws of the Game, the referees' interpretation of the rules, as well as the coaches' and players' attitudes towards fair play and high-risk game situations.[39–42] To our knowledge, no risk factor studies or preventive measures specifically aimed at contact injuries have been implemented in female youth football. However, it has been shown in international female tournaments that the decision of the referee does not reflect the injury risk of sliding-in tackle.[43] Thus, it seems unreasonable to expect referees on a lower level to make correct decisions based on a subjective judgment of injury risk.

The current results also suggest that skill level should be addressed as a possible confounder in studies on other risk factors for injury. However, because skill level was registered in relation to the skill level of teammates, our findings might not be valid within populations consisting of multiple teams or leagues. Teams in female youth football are often characterised by large variations in skill level, larger than on the senior level and in male football. Thus, we do not know if the results can be generalised to both sexes or other age groups.

What is already known on this topic

- Football performance is composed of an admixture of technical, tactical, physiological, psychological, psychosocial and anthropometric factors.
- Knowledge of how these factors influence the injury risk in football is limited.

What this study adds

- Players with good technical, tactical and physiological football skills may be at greater risk of injury than their less skilled teammates.
- Subsequent studies are needed to determine whether stricter enforcement of the Laws of the Game and modification of coaches' and players' attitudes towards fair play and high-risk game situations are required.

CONCLUSION

Players with good football skills were at greater risk of injury than their less skilled teammates. The increased injury risk was most evident not only in the players with high technical and tactical skills but also in physically strong players. Players skilled in these attributes were generally more susceptible to injuries overall, lower extremity injuries, acute injuries and contact injuries.

Acknowledgements We thank the project assistants (Birgitte Lauersen, Ellen Blom, Olav Kristianslund, Agnethe Nilstad and Tone Wigemyr), the coaches and the players who participated in this study.

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

Competing interests None.

Ethics approval This study was conducted with the approval of the Regional Committee for Medical Research Ethics, South-Eastern Norway Regional Health Authority, Norway.

Provenance and peer review Not commissioned; externally peer reviewed.

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Paper IV

Scand J Med Sci Sports 2010
doi: 10.1111/j.1600-0838.2010.01174.x

SCANDINAVIAN JOURNAL OF
MEDICINE & SCIENCE
IN SPORTS

Injury risk on artificial turf and grass in youth tournament football

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Accepted for publication 7 June 2010

The aim of this prospective cohort study was to investigate the risk of acute injuries among youth male and female footballers playing on third-generation artificial turf compared with grass. Over 60 000 players 13–19 years of age were followed in four consecutive Norway Cup tournaments from 2005 to 2008. Injuries were recorded prospectively by the team coaches throughout each tournament. The overall incidence of injuries was 39.2 (SD: 0.8) per 1000 match hours; 34.2 (SD: 2.4) on artificial turf and 39.7 (SD: 0.8) on grass. After adjusting for the potential confounders age and gender, there was no difference in the overall risk of injury [odds ratio (OR): 0.93 (0.77–1.12), *P* = 0.44] or in the risk of time loss injury [OR: 1.05 (0.68–1.61), *P* = 0.82] between artificial turf and grass. However, there was a lower risk of ankle injuries [OR: 0.59 (0.40–0.88), *P* = 0.008], and a higher risk of back and spine [OR: 1.92 (1.10–3.36), *P* = 0.021] and shoulder and collarbone injuries [OR: 2.32 (1.01–5.31), *P* = 0.049], on artificial turf compared with on grass. In conclusion, there was no difference in the overall risk of acute injury in youth footballers playing on third-generation artificial turf compared with grass.

Grass is the traditional playing surface in football both for matches and training on the elite level. However, artificial turfs have inherent advantages such as longer playing hours, lower maintenance costs, better resilience to tough climatic conditions, and multi-purpose application. Because of these benefits, artificial turf is becoming a common playing turf not only among youth but also in professional football.

Since its introduction in the 1970s, artificial turf has been developed and refined continuously. The first and second generations of artificial turfs were hard and shoe-surface traction was high, which made the playing characteristics different from natural grass and the injury risk higher (Engebretsen & Kase, 1987; Árnason et al., 1996). Third-generation artificial turfs were introduced in the late 1990s and consisted of longer and much more spread turf fibers filled with rubber granules. With adjusted hardness and traction, the playing characteristics and player movement patterns on the new turfs resembled those on grass better (Andersson et al., 2008).

However, concerns have been raised that the injury risk of playing on third-generation artificial turfs may still be higher compared with playing on grass. Only a few studies have looked into this; none conducted among adolescent players of both genders. Ekstrand et al. (2006) followed 10 male elite football clubs playing on third-generation artificial turf during three seasons from 2003 to 2005. No difference in the incidence of match or training injuries was found between artificial turf and grass, although the incidence of ankle sprains on artificial turf was almost twice and lower extremity strains almost half of that found on grass. Fuller et al. (2007a, b) followed male and female college football teams for two seasons in 2005 to 2006 and reported no major difference in the overall risk, severity, nature, or cause of match or training injuries between the two turf types. After following 14–16-year-old females over the 2005 season, Steffen et al. (2007) reported that there was no difference in the overall risk of injury between artificial turf and grass. However, the incidence of severe match injuries on artificial turf was twice that found on grass. Aoki et al. (2010) monitored six teams consisting of 12–17-year-old males in the 2005 season, and observed no difference in the incidence of acute injuries between artificial turf and grass during training or matches. However, training on artificial turf was associated with chronic low back pain.

The aim of this study was to investigate the risk of acute injuries among youth male and female footballers playing on third-generation artificial turf compared with grass.

Materials and methods

A prospective cohort design was used for the study. Data were collected from 2005 to 2008 in the Norway Cup, which since its start in 1972 has become one of the largest international youth football tournaments. It is arranged in Oslo in the first week of August every year, with more than 1500 teams and 17 000 players participating. The matches are played from 08:00 hours until 20:00 hours for six consecutive days in large recreational areas with more than 40 playing fields.

Five of the fields were covered with third-generation artificial turf. All 11-a-side classes were included, corresponding to boys and girls 13–19 years of age. The play-off matches and 7-a-side matches were excluded because they were played on natural grass only. In order to have a sufficient number of playing fields, most of the 11-a-side fields covered with natural grass are somewhat smaller than the official regulations by the Football Association of Norway (NFF). Over the four tournaments, the study comprised more than 4000 teams and 60 000 players; approximately one-third of these were girls.

The study was approved by the Regional Committee for Medical Research Ethics, South-Eastern Norway Regional Health Authority, Norway.

Recording of data

The injury recording involved the team coaches and the referees. Before each match, the referee visited the referee department to receive two injury record forms as well as the scorecard. The referee handed out one injury record form to the coach of each team. The coaches were asked to fill in the form if any injuries occurred during the match. Immediately after the match, the referee collected the injury forms and delivered them to the tournament transport unit. The main task of this unit was to transport the scorecard and injury forms from the playing field to the technical department, where the injury data were plotted into a database by trained personnel.

The team coaches and the referees were informed specifically about the purpose and methodology of the study before the start of the tournament. The referees were provided with a letter detailing the study when they checked in to the referee department. Also, the day before tournament start all the referees were gathered in a plenary meeting where we described the procedures for the injury registration. The referees were also followed up every day by study personnel in the referee department. Every team coach was informed about the study in a letter distributed to them 1 month before attending the tournament, as well as on arrival during check-in.

The injury record form was a bilingual (Norwegian/English) check-box form. The form included instructions on how to record the information. The coaches recorded the location, type, severity, and cause (acute/overuse; contact/non-contact) of injury. The referee completed the team names and the unique match ID, which allowed for subsequent data extraction of the age and gender of the players, as well as the playing field number and turf type (artificial turf or natural grass). No personal data were recorded in the injury forms or stored in the injury database, and informed consent was not obtained.

An injury was defined as any injury, painful condition, or physical complaint sustained by a player in a Norway Cup match, irrespective of the need for medical attention or time loss from football activities (Fuller et al., 2006). We did not include injuries or other medical conditions occurring outside Norway Cup matches. Contact injuries were defined as injuries resulting from contact with another player, whereas non-contact injuries were defined as injuries occurring without contact with another player. Acute injuries were defined as injuries with a sudden onset, associated with a known trauma. Overuse injuries were defined as injuries with a gradual onset and no known trauma. Because overuse injuries have a gradual onset, they could not be attributed to a particular turf type, and hence, their injury incidence could not be compared between turf types. The injury recording method did not allow for any assessment of injury exacerbations or recurrences. Injuries were grouped into four categories of severity by the coaches according to the expected length of absence from matches and training sessions: minimal (1–3 days); mild (4–7 days); moderate (8–28 days); and severe (>28 days). Match exposure was calculated on a team basis on the assumption that each match involved 11 players and lasted for 40, 50, or 60 min, according to the age class.

Statistical methods

We used ordinal regression analyses with injuries as the dependent variable to estimate the risk of injury on artificial turf and grass. We used logistic regression analyses in subgroups where the number of injuries was limited. All estimates were adjusted for the potential confounders age and gender. In the regression analyses, tests of interaction between turf type, age, and gender were performed by adding three-way and two-way cross-product terms. If significant interactions were not identified, the three-way cross-product term was eliminated and the procedure was repeated. If significant interactions were still not found, the two-way cross-product terms were eliminated and one-way interactions with injury risk were tested. We used the relative risk (RR) of the injury incidences on artificial turf and grass for comparison with the adjusted odds ratio (OR). Grass was used as a reference group. The summary measure of injury incidence (i) was calculated according to the formula $i = n/e$, where n is the number of injuries and e the sum of exposure expressed in match hours. Injury incidences are presented as means with standard errors. OR and RR are presented with 95% confidence intervals (CI). Two-tailed P-values ≤ 0.05 were regarded as significant. All analyses were conducted in SPSS for Windows, version 15 (SPSS, Chicago, Illinois, USA).

Results

From the Norway Cup 2005 through 2008, data were collected from 7848 matches; 5491 (70%) played by boys and 2357 (30%) by girls. The total exposure to football was 62 597 match hours; 6022 (10%) on artificial turf and 56 575 (90%) on grass. A total of 2454 injuries were recorded; 206 (8%) on artificial turf and 2248 (92%) on grass. Two hundred seventy-two of the injuries (11%) were expected to lead to absence from training and matches for at least 1 day. Of these, 25 (9%) occurred on artificial turf and 247 (91%) on grass. The descriptive injury and exposure data for both genders and the four age classes are shown in Table 1.

Injury pattern on artificial turf and grass

The overall incidence of injuries was 39.2 (SD: 0.8) per 1000 match hours; 34.2 (SD: 2.4) on artificial turf and 39.7 (SD: 0.8) on grass. The incidence of time loss injuries was 4.3 per 1000 match hours; 4.2 (SD: 0.8) on artificial turf and 4.4 (SD: 0.3) on grass. The incidence of injuries for boys was 31.3 (SD: 2.6) and

38.8 (SD: 1.0) per 1000 match hours on artificial turf and grass, respectively. For girls, the incidence was 42.7 (SD: 5.3) and 41.9 (SD: 1.6) injuries per 1000 match hours on artificial turf and grass, respectively. After adjusting for the potential confounders age and gender, there was no difference in the overall risk of injury (OR: 0.93; 95% CI: 0.77–1.12; $P = 0.44$) or in the risk of time loss injury (OR: 1.05; 95% CI: 0.68–1.61; $P = 0.82$) between artificial turf and grass.

The injury rates for most subcategories of injury types and locations were similar on artificial turf and grass (Table 2). However, while there was no difference in the risk of ankle sprains between the two surfaces (rate ratio: 0.39; 95% CI: 0.12–1.23), the risk of ankle injuries overall was almost half on artificial turf compared with on grass. In contrast, the rate of injuries to the back and spine, as well as to the shoulder and clavicle, was twice as high on artificial turf compared with on grass. There was no difference in the injury rate for subcategories of expected absence from match and training between the turf types.

Interestingly, the occurrence of abrasions and lacerations was low on both artificial turf and grass, and no difference was seen between the two surfaces.

Table 1. Descriptive injury and exposure data for both genders and the four age classes

Age class	Exposure			Injuries		
	Boys	Girls	Total	Boys	Girls	Total
13 years	9095	2601	11 696	309	102	411
14 years	12 154	4576	16 730	559	210	769
15–16 years	16 945	8163	25 108	640	312	952
17–19 years	6028	3036	9064	175	147	322

Discussion

The main findings of this prospective cohort study were that there was no difference in the risk of acute injuries overall or acute time-loss injuries between boys and girls playing tournament football on third-generation artificial turf compared with grass. This is the first study to assess the relationship between the turf types and risk of injury in both male and female youth football.

Table 2. Number, incidence, and risk of acute injuries on artificial turf and grass

	Artificial turf		Grass		RR (95% CI)	Adjusted OR (95% CI)†
	Injuries	Incidence	Injuries	Incidence		
Injury type						
Contusion	83	13.8 ± 1.5	883	15.6 ± 0.5	0.88 [0.71–1.11]	0.91 [0.69–1.19]
Sprain	6	1.0 ± 0.4	123	2.2 ± 0.2	0.46 [0.20–1.04]	0.52 [0.23–1.18]
Strain	13	2.2 ± 0.6	168	3.0 ± 0.2	0.73 [0.42–1.28]	0.88 [0.50–1.52]
Fracture	2	0.3 ± 0.2	14	0.2 ± 0.1	1.34 [0.31–5.91]	1.31 [0.30–5.78]
Dislocation	1	0.2 ± 0.2	20	0.4 ± 0.1	0.47 [0.06–3.50]	0.47 [0.06–3.49]
Abrasion/laceration	5	0.8 ± 0.4	55	1.0 ± 0.1	0.85 [0.34–2.13]	0.89 [0.36–2.25]
Injury location						
Lower body	116	19.3 ± 1.8	1596	28.2 ± 0.7	0.68 [0.57–0.82]**	0.81 [0.66–1.01]
Foot	25	4.2 ± 0.8	276	4.9 ± 0.3	0.85 [0.57–1.28]	1.05 [0.70–1.58]
Ankle	26	4.3 ± 0.8	476	8.4 ± 0.4	0.51 [0.36–0.76]**	0.59 [0.40–0.88]**
Lower leg	14	2.3 ± 0.6	189	3.3 ± 0.2	0.70 [0.40–1.20]	0.71 [0.41–1.24]
Knee	28	4.6 ± 0.9	314	5.6 ± 0.3	0.84 [0.57–1.23]	0.96 [0.65–1.42]
Thigh	12	2.0 ± 0.6	236	4.2 ± 0.3	0.48 [0.27–0.85]*	0.69 [0.41–1.15]
Hip	4	0.7 ± 0.3	48	0.8 ± 0.1	0.78 [0.28–2.17]	0.99 [0.39–2.50]
Groin	7	1.2 ± 0.4	57	1.0 ± 0.1	1.15 [0.53–2.53]	0.85 [0.34–2.13]
Upper body	88	14.6 ± 1.6	601	10.6 ± 0.4	1.38 [1.10–1.72]**	1.23 [0.93–1.61]
Back/spine	18	3.0 ± 0.7	76	1.3 ± 0.2	2.23 [1.33–3.72]**	1.92 [1.10–3.36]*
Stomach/chest	10	1.7 ± 0.5	108	1.9 ± 0.2	0.87 [0.46–1.66]	1.02 [0.54–1.90]
Arm/hand/fingers	11	1.8 ± 0.6	65	1.1 ± 0.1	1.59 [0.84–3.01]	1.16 [0.62–2.18]
Shoulder includes clavicle	7	1.2 ± 0.4	29	0.5 ± 0.1	2.27 [0.99–5.18]	2.32 [1.01–5.31]*
Neck	4	0.7 ± 0.3	53	0.9 ± 0.1	0.71 [0.26–1.96]	2.19 [0.83–5.80]
Head	38	6.3 ± 1.0	270	4.8 ± 0.3	1.32 [0.94–1.86]	1.23 [0.84–1.80]
Severity						
Minimal injuries (1–3 days)	17	2.8 ± 0.7	150	2.7 ± 0.2	1.07 [0.65–1.76]	1.12 [0.66–1.89]
Mild injuries (4–7 days)	6	1.0 ± 0.4	39	0.7 ± 0.1	1.45 [0.61–3.41]	1.50 [0.63–3.56]
Moderate injuries (8–28 days)	1	0.2 ± 0.2	37	0.7 ± 0.1	0.25 [0.04–1.85]	0.28 [0.04–2.05]
Severe injuries (>28 days)	1	0.2 ± 0.2	21	0.4 ± 0.1	0.45 [0.06–3.33]	0.49 [0.07–3.69]

$^{*}P<0.05$, $^{**}P<0.01$.

†Adjusted for age and gender.

RR, relative risk; CI, confidence intervals; OR, odds ratio.

The main results are consistent with the conclusions in previous studies evaluating the risk of injury on third-generation artificial turfs and grass in male elite players (Ekstrand et al., 2006), male and female college players (Fuller et al., 2007a, b), 14–16-year-old female players (Steffen et al., 2007), and 12–17-year-old male players (Aoki et al., 2010). The only significant difference in injury pattern in the current study was a lower risk of ankle injuries on artificial turf and a higher risk of back and spine injuries, as well as injuries to the shoulder and clavicle. However, interpretation of these differences in injury pattern should be made with caution. The comparison of injury incidences between surfaces for specific injury subgroups is restricted by small numbers, and the possibility of type II error resulting from limited data must be considered. Furthermore, 43% of the injuries were recorded with missing injury mechanism data (data not shown), indicating that the coaches must have found this difficult to determine. Hence, considering the low validity of the injury mechanism data, further analyses were omitted.

The two main factors involved in surface-related football injuries are the friction between the surface and the shoe and the stiffness of the surface (Nigg & Yeadon, 1987). Although the grass fields in Norway Cup are mowed before the start of the tournament, they are often characterized by a soft, but uneven surface. Such rough field conditions can play a role in an injury mechanism for ankle sprains, which may explain the increased risk of ankle injuries found on grass. Contrary, Ekstrand et al. (2006) found that elite male players had a higher risk of ankle injuries on artificial turf. However, the grass fields in professional football are assumedly of much higher standard than the grass fields in this youth amateur football tournament.

Minor abrasions and friction burns have been reported to be more common on artificial turf, albeit on older generations (Winterbottom, 1985; Nigg & Segesser, 1988; Ekstrand & Nigg, 1989; Gaulrapp et al., 1999). However, using the broad injury definition we could examine this, and our findings indicate that such injuries were not a problem with the new generation of artificial turfs. Furthermore, it should be noted that although "third-generation artificial turf" is the collective term for the latest artificial surfaces, there are several manufacturers who deliver various brands of artificial turfs. The brands may have dissimilar surface stiffness and friction, depending on the fiber length and thickness, the type and amount of rubber granules, and whether an optional shock-absorbing rubber pad is molded underneath the surface.

A strength of the study is that it spanned across four consecutive tournaments from 2005 to 2008, including almost 8000 matches and more than 60 000 match hours. Furthermore, the time span of our data collection minimized the risk of biased results with respect to the playing fields being influenced by a certain weather condition. Throughout the four tournaments, the players played both on soft and slippery surfaces resulting from rain, as well as on harder surfaces with more friction resulting from sun and dry weather conditions.

The number of matches played during the Norway Cup tournament (almost 2000 11-a-side matches played in less than a week) makes it difficult to survey the injury frequency strictly using medically trained personnel. The main limitation of the study is that the data collection depended on the coaches and the referees. Although they received information detailing the injury recording procedures, they were not medically trained to ensure good validity and reliability in determining the presence of injury, let alone determining the diagnosis and prognosis. The results concerning the type and severity of injury must therefore be interpreted with caution. Furthermore, when studying epidemiology or etiology of football injuries the time loss definition of injury is most commonly used. However, we used the broader definition of injury from the consensus statement, which includes all painful conditions or physical complaints irrespective of the need for medical attention or time loss from football activities (Fuller et al., 2006). A limitation of this definition is that it will include a number of physical complaints and bodily conditions that may not result in significant negative consequences for the player. Even so, in the current study this definition was likely to provide better reliability in the data collection, compared with using the time loss definition, which would rely on the coaches' ability to estimate whether an injury would lead to absence from training and matches.

To examine to which degree the coaches recorded all occurring injuries according to the injury definition, we conducted a compliance study in the 2005 tournament. Three physicians from our research center observed and recorded all physical complaints and other events possibly related to injury in 49 randomly selected matches. In cases where it was difficult to ascertain whether an injury had occurred, the physician contacted and interviewed the respective player immediately after the match. The results showed that the coaches recorded less than half of the injuries that occurred (data not shown). With respect to internal validity, however, we could not detect any systematic errors in the coaches' recording of injuries on the two turf types.

In conclusion, there was no difference in the overall rate of acute injury among boys and girls playing on third-generation artificial turf compared with grass.

Perspectives

The current study supports the findings in previous studies addressing the risk of injury on artificial turf and grass in football. Although there are some conflicting results regarding subgroups of injuries, the overall risk of acute injury appears to be similar on the two surfaces. However, the significance of artificial turf in the etiology of overuse injuries is still uncertain. For instance, it has been speculated that higher ground stiffness in particular can have an influence on overuse injuries (Hort, 1977; Ekstrand & Nigg, 1989). Furthermore, in Norway Cup all teams play on both artificial turf and grass, and continuously switch between the two surfaces. Studies assessing the injury risk on previous generations of artificial turf have discussed whether players' lack of adaptation to a surface and rapid changes between different types of playing surfaces is a precursor to overuse injury, such as lower limb and lower back pain (Ekstrand & Gillquist, 1983; Engebretsen & Kase, 1987; Ekstrand & Nigg, 1989; Hagel et al., 2003). However, such theories are hard to test in epidemiological studies using the traditional methodology to record injuries. By definition, overuse injuries occur over time with a gradual onset, and the traditional study design and methodology does not allow for attribution of overuse injury to a specific event or a particular turf type. Even if a player first experience symptoms during a specific match, the injury may have gradually been incurred as a result of long-term exposure to another turf type, rapid changes between different turf types, or other factors. To investigate whether overuse injuries are associated with a specific turf type, the ideal design would be a randomized controlled trial where players are randomized to train and play matches exclusively on either artificial turf or grass. For practical reasons, such a study is not feasible and will probably never occur. A more realistic approach would be to compare teams training and playing their home matches on artificial turf to teams who mainly train and play on grass (Ekstrand et al., 2006; Aoki et al., 2010). In planning new studies, one should in any case consider adopting novel methodology developed to record and quantify the risk and severity of overuse injuries in sport (Bahr, 2009). Through more advanced statistical modeling, it may also be possible to detect if there is an increased injury risk associated with rapid switches in playing surface.

Key words: risk factors, surface, injures, adolescence, hardness, friction.

Acknowledgements

The Oslo Sports Trauma Research Center has been established at the Norwegian School of Sport Sciences through generous grants from the Royal Norwegian Ministry of Culture and Church Affairs, the South-Eastern Norway Regional Health Authority, the Norwegian Olympic Committee and Confederation of Sport, and Norsk Tipping AS. In addition, this study was supported by grants from the FIFA Medical Assessment and Research Centre. We thank the project assistants (John Bjørneboe, Eirik Grindaker, Kristian Gulbrandsen, Mats Jansen, Håvard Nygaard, Frode Rauneshaug, Johanne Støren Stokke, Tuva Torsrud, Vegar Vallestad, and Hallvar Waage), the coaches, and the referees who participated in this study. We thank Ingar Holme for the statistical advice. The authors highly appreciate the cooperation of the Norway Cup administrators who kindly helped arrange for the data collection.

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Appendices 1-5

Appendix 1

SENTER FOR Idrettsskadeforskning KLOKE AV SKADE

SPILLEKLAR!

Trenings- og kampskjema

Lagnavn:	ID:	Uke:	Utfylt av:

	Man	Tirs	Ons	Tors	Fre	Lør	Søn
Dato	1.okt	2.okt	3.okt	4.okt	5.okt	6.okt	7.okt
Balltrening (min.)							
Seriekamp (min.)							
Annen kamp (min.)							
Annen trening (ikke fotball) (min.)							
Kunstgress (sett X)							
Naturgress (sett X)							
Grus (sett X)							
Innendørs (sett X)							
SPILLEKLAR utført (sett X)							

Id	Spillernavn	Man	Tirs	Ons	Tors	Fre	Lør	Søn
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
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31								
32								
33								
34								
35								
36								

S = Skadet gjennom fotball

Husk info om skadde spillere på baksiden

SENTER FOR Idrettsskadeforskning KLOKE AV SKADE

Informasjon om skadde spillere

Navn: **Skadedato:**

Skadesituasjon (beskriv kort hva som skjedde og hvor på kroppen):

***

Navn: **Skadedato:**

Skadesituasjon (beskriv kort hva som skjedde og hvor på kroppen):

***

Navn: **Skadedato:**

Skadesituasjon (beskriv kort hva som skjedde og hvor på kroppen):

***

Kommentarer:

Appendix 2

SKADESKJEMA

A. SPILLERDATA

Klubb: Samtykke: Ja ☐ Nei ☐

Spillerens navn: Tlf: Fødselsdato:

B. SKADEDATA

Skadedefinisjon:
Akutte skader og belastningsskader som medfører at spilleren trenger medisinsk behandling, mister deler av trening/kamp eller ikke kan delta på neste trening/kamp.

Skadedato:	Skaden skjedde:	FOR KAMPSKADER:	FOR TRENINGSSKADER:
	☐ I kamp ☐ På trening	Type kamp: ☐ Seriekamp ☐ Cup-/Turneringskamp ☐ Treningskamp ☐ Annen kamp	Type trening: ☐ Fotballtrening ☐ Annen fellestrening organisert av laget

Skaden skjedde:
I kamp – når?: ☐ Under oppvarming ☐ 1. omgang ☐ 2. omgang
På trening - når? : ☐ Under oppvarming ☐ Etter oppvarming/resten av treningen
☐ Vet ikke

Skadetype:	Skaden er:	Underlag skaden skjedde på:
☐ Akutt skade ☐ Belastningsskade	☐ Ny skade ☐ Forverring av pågående skade ☐ Residiv av gammel skade	☐ Gress ☐ Kunstgress ☐ Grus ☐ Innendørs/ annet

Spillerfunksjon:
☐ Målvakt ☐ Forsvar ☐ Midtbane ☐ Ving ☐ Spiss

Kontakt med annen spiller da skaden skjedde: ☐ Direkte kontakt ☐ Indirekte kontakt ☐ Nei

Aktivitet da skaden skjedde: ☐ Takling ☐ Hodeduell ☐ Løp ☐ Kollisjon m/ spiller
☐ Fall ☐ Kollisjon m/ annet ☐ Annen

Skadet kroppsdel:
- ☐ Hode/ansikt
- ☐ Nakke/hals
- ☐ Skulder, inkl. kravebein
- ☐ Overarm
- ☐ Albue
- ☐ Underarm
- ☐ Håndledd
- ☐ Hånd/fingre/tommel
- ☐ Brystkasse/ribbebein/brystrygg
- ☐ Mageregion inkl. indre organer
- ☐ Nedre rygg/bekken/sacrum
- ☐ Hofte/Lyske
- ☐ Lår – fremside
- ☐ Lår - bakside
- ☐ Kne
- ☐ Legg, inkl. Akilles sene
- ☐ Ankel
- ☐ Fot/tå

Dominant bein:
☐ Høyre ☐ Venstre

Skadet side:
☐ Høyre ☐ Venstre ☐ Ingen ☐ Begge

Skadetype:
- ☐ Støtskade/kontusjon
- ☐ Leddbåndskade (forstuvning)
- ☐ Seneskade
- ☐ Muskelskade (strekk, avrivning)
- ☐ Ute av ledd (luxasjon)
- ☐ Brudd, inkl. tretthetsbrudd
- ☐ Sår/kutt
- ☐ Hjernerystelse
- ☐ Nerveskade
- ☐ Tannskade
- ☐ Annet - hva?

……………………………………

Hvor lang tid tok det før spilleren var kampklar eller kunne delta for fullt i fotballtreningen:
☐ 1-3 dager ☐ 4-7 dager ☐ 8-28 dager ☐ >28 dager ☐ Ingen fravær

Utfylt av: Dato:

Appendix 3

INTERVJUGUIDE

Hensikt:

- gjennomføre en evaluering av oppvarmingsprogrammet SPILLEKLAR!
  Denne delen er basert på en modifisert versjon av intervjuguiden som ble benyttet av Steffen og medarbeidere i prosjektet "Bedre fotball uten skader" i 2005
- kartlegge holdninger til skadeforebyggende trening blant trenere for fotballag med unge kvinnelige fotballspillere i alderen 14 til 16 år

Lag:	**Lagleder:**

EN EVALUERING AV OPPVARMINGSPROGRAMMET SPILLEKLAR! OG EN KARTLEGGING AV HOLDNINGER BLANT TRENERNE

1) Hvordan vil du karakterisere spillernes oppfatning av programmet?

Positivt ◯ Negativt ◯ Nøytralt ◯

2) Når du vurderer programmet som helhet, hvor enig er du i følgende utsagn;

a) Programmet er spennende

Meget enig	Enig	Usikker	Uenig	Meget uenig
◯	◯	◯	◯	◯

b) Programmet er velegnet som oppvarmingsprogram for fotballspillere

Meget enig	Enig	Usikker	Uenig	Meget uenig
◯	◯	◯	◯	◯

c) Jentene var godt motiverte for å bruke programmet

Meget enig	Enig	Usikker	Uenig	Meget uenig
◯	◯	◯	◯	◯

d) Programmet gir god effekt på spillernes fysiske form

Meget enig Enig Usikker Uenig Meget uenig

e) Programmet vil forebygge skader, dersom det brukes systematisk

Meget enig Enig Usikker Uenig Meget uenig

f) Jeg kommer til å bruke programmet også neste sesong (hvis jeg skal trene et lag)

Meget enig Enig Usikker Uenig Meget uenig

3) Du vil nå bli bedt om å vurdere de ulike øvelsene i programmet. Vi er interessert i å få vite om du oppfattet øvelsen som;

A- **Viktig** eller **mindre viktig** for å forebygge skader

B- **Morsom**, **grei** eller **kjedelig**

C- **For utfordrende**, **passe vanskelig** eller **for lett** for spillergruppen du trener

D- **Relevant** eller **mindre relevant** for fotballspillere med tanke på prestasjon

Øvelse	**A)Viktig/ Mindre viktig**		**B)Morsom/ Grei/ Kjedelig**			**C)For utfordrende/ Passe/ For lett**			**D)Relevant/ Mindre relevant**	
1) Løpsøvelser I										
2) Benken										
3) Sidehev										
4) Nordic hamstrings										
5) Ettbeins balanse										
6) Knebøy										
7) Spensthopp										
8) Løpsøvelser II										

4) Hvilken del av SPILLEKLAR! tror du er mest nyttig for å kunne forebygge skader?

a) Løpsøvelser I ◯ b) Styrke/ spenst ◯ c) Balanse ◯ d) Løpsøvelser II ◯

5) Hva synes du om progresjonen på øvelsene i programmet?

Meget god ◯ God ◯ Mindre god ◯ Lite god ◯

6) Har spillerne fått aktiv oppfølging og feilretting underveis?

Alltid ◯ Ofte ◯ Av og til ◯ Sjelden ◯ Aldri ◯

7) Har spillerne gjennomført øvelsene fra SPILLEKLAR! utenom organiserte fellestreninger?

Ofte ◯ Av og til ◯ Sjelden ◯ Aldri ◯ Vet ikke ◯

8) I hvilken grad opplever du at programmet har påvirket antall skader hos ditt lag?

a) Akutte skader

Flere skader ◯ Omtrent som før ◯ Færre skader ◯ Vet ikke ◯

b) Belastningsskader

Flere skader ◯ Omtrent som før ◯ Færre skader ◯ Vet ikke ◯

9) I hvilken grad opplever du at programmet har påvirket spillernes prestasjon i form av;

a) Pasnings- og skuddferdigheter?

Høy grad ◯ Middels grad ◯ Noen grad ◯ Liten/ ingen grad ◯

b) Bevegelsesmengde og –intensitet, og hurtighet?

Høy grad ◯ Middels grad ◯ Noen grad ◯ Liten/ ingen grad ◯

10) Hva er de viktigste grunnene til at dere ikke fikk benyttet programmet mer enn dere gjorde? Velg inntil 3 alternativer:

a) Jentene var ofte ikke motivert ◯

b) Programmet inneholder for lite trening med ball ◯

c) Programmet er for vanskelig ◯

d) Det var få jenter på trening på grunn av andre aktiviteter ◯

e) Programmet tar for lang tid ◯

f) Det ble tungvint å organisere ◯

g) Programmet er ikke relevant i forhold til skadeforebygging ◯

11) Hvem har for det meste igangsatt/ instruert programmet?

Hovedtrener ◯ Ass-trener ◯ Spillerne selv ◯ Andre (spesifiser)…………

12) Hva er din bakgrunn og erfaring som trener?

Ingen ◯ Gymlærer ◯ Trener 1(B-kurs) ◯ C-kurs ◯ D-kurs ◯ Annen ……………

13) Hvor ofte trente laget per uke (gjennomsnitt)? **Tid per økt?**

1gang ◯ 2 ganger ◯ 3 ganger ◯ >3 ganger ◯ 1t ◯ 1,5 t ◯ 2 t ◯ >2 t ◯

14) Har du forslag til øvelser som kunne gjort programmet SPILLEKLAR! enda bedre?

……………………………………………………………………………………………………..

……………………………………………………………………………………………………..

15) I hvor stor grad opplever du at dine spillere har en risiko for fotballskader?

Høy risiko	Middels risiko	Lav risiko	Ingen risiko
◯	◯	◯	◯

16) Tror du det er noen forskjell i skaderisiko mellom gutter og jenter innen fotball?

Jenter mest utsatt	Gutter mest utsatt	Ingen forskjell
◯	◯	◯

17) Hva tror du er den viktigste årsaken til skader blant spillerne på ditt lag?

Velg inntil 3 alternativer:

- **a)** For dårlig grunntrening ◯
- **b)** For lite trening ◯
- **c)** For mange kamper ◯
- **d)** Samtidig deltakelse i andre idretter ◯
- **e)** Stygge taklinger ◯
- **f)** Sko/ underlag/ dekke ◯
- **g)** Annet……………………………………

18) Hvor viktig synes du det er å bruke tid på skadeforebyggende trening?

Svært viktig	Viktig	Mindre viktig	Uviktig
◯	◯	◯	◯

19) Hvor enig eller uenig er du i følgende påstander:

	Meget enig	Enig	Usikker	Uenig	Meget uenig
Påvirkning fra media og kjente profiler har stor betydning for motivasjonen til å gjennomføre skadeforebyggende trening					
Det er først og fremst innen fotball på elitenivå det er viktig å fokusere på skadeforebygging					
Det er viktigere å bruke treningstiden til å spille fotball enn til å gjennomføre et program med skadeforebyggende hensikt					
Trenerens motivasjon har ingen innvirkning på jentenes motivasjon til å gjennomføre skadeforebyggende trening					
Spillernes motivasjon og konsentrasjon under utførelsen av øvelsene i SPILLEKLAR! har vært god					
Opplæringen og oppfølgingen laget fikk gjennom fotballsesongen var dårlig					
Som trener benyttet jeg SPILLEKLAR! fordi jeg følte meg forpliktet til det					
Spillernes bevissthet og kontroll over kne- og ankelposisjon i finter og landinger har bedret seg gjennom fotballsesongen					

20) Hva var den største motivasjonsfaktoren for å gjennomføre SPILLEKLAR! gjennom fotballsesongen?

a) Troen på at programmet kan redusere antall skader ◯

b) Troen på at programmet kan bedre spillernes prestasjon ◯

c) Påvirkning fra andre (omgivelser, media, etc) ◯

d) Pliktfølelse ◯

21) Dersom du har trent lag tidligere, har du bevisst benyttet noen form for trening med skadeforebyggende hensikt?

Ja, i stor grad ◯ Ja, av og til ◯ Sjelden ◯ Nei, aldri ◯ Ikke vært trener tidligere ◯

22) Hva kunne vært gjort annerledes for å øke din motivasjon som trener for å benytte SPILLEKLAR?

……………………………………………………………………………………………………..

……………………………………………………………………………………………………..

23) Har du som trener andre kommentarer eller tilbakemeldinger du ønsker å formidle etter å ha deltatt i prosjektet SPILLEKLAR! gjennom fotballsesongen 2007?

…………………………………………………………………………………………………….

…………………………………………………………………………………………………….

Appendix 4

13642

SENTER FOR Idrettsskadeforskning KLOKE AV SKADE

FOTBALLFERDIGHET

SPILLERDATA

Spiller-ID: ☐☐☐☐☐ **Klubb:** ....

Spillernavn: ....

Fylles ut av lagets trener: .... Dato: ....

Vurdèr spilleren og sett kryss i det tilhørende rubrikkfeltet der du mener spilleren befinner seg i forhold til gjennomsnittet for din spillergruppe. For hvert spørsmål kan en spiller befinne seg i en av de fire ferdighetsnivåene: blant de 25 % svakeste, blant de 25 % under middels, blant de 25 % over middels eller blant de 25 % beste.

Sett kun ett kryss per ferdighet. Bruk kulepenn og kryss av i hele ruten: X

1. TEKNIKK

	Svakest 25%	Middels 25%	Middels 25%	Best 25%
Mottak - medtak (ballkontroll)	☐	☐	☐	☐
Tilslag (kraft, presisjon)	☐	☐	☐	☐
Heading (tilslag, timing)	☐	☐	☐	☐
Drible (føre, finte, vende)	☐	☐	☐	☐
Taklingsferdighet	☐	☐	☐	☐

2. TAKTIKK / VALG

	Svakest 25%	Middels 25%	Middels 25%	Best 25%
A: Valg med ball: Pasning, dribling, avslutning (spilleforståelse)	☐	☐	☐	☐
B: Valg uten ball: Offensivt	☐	☐	☐	☐
Defensivt	☐	☐	☐	☐

3. FYSIKK

	Svakest 25%	Middels 25%	Middels 25%	Best 25%
Utholdenhet	☐	☐	☐	☐
Hurtighet	☐	☐	☐	☐
Styrke, duellstyrke	☐	☐	☐	☐
Koordinasjon, balanse, tyngdeoverføring	☐	☐	☐	☐

Alle skjemaene sendes samlet i retur til Senter for idrettsskadeforskning. Bruk frankert konvolutt. Ved spørsmål, ring Torbjørn på 23 26 23 76 eller 997 04 713, eller send e-post til spilleklar@nih.no.

Takk!

Appendix 5

Oslo Sports Trauma RESEARCH CENTER

NORGES FOTBALLFORBUND – THE FOOTBALL ASSOCIATION OF NORWAY

INJURY REGISTRATION NORWAY CUP 2008 – INFORMATION

- Please register all injuries, painful conditions or physical complaints occurring during the match, even if the player is able to continue to play.
- The form has room for up to 8 injuries - *use one column for each injury.*
- The form is filled out by crossing out the circles.
- The coach can add additional comments in the specified field.
- The completed form is collected by the referee immediately after the game.

Match number: ______ **Field name:** ______ **Team name:** ______

☐ **There were no injuries in this match.** **Signature team coach:** ______

Injury	#1	#2	#3	#4	#5	#6	#7	#8
1 Body part								
Foot	○	○	○	○	○	○	○	○
Ankle	○	○	○	○	○	○	○	○
Lower leg	○	○	○	○	○	○	○	○
Knee	○	○	○	○	○	○	○	○
Thigh	○	○	○	○	○	○	○	○
Hip	○	○	○	○	○	○	○	○
Groin	○	○	○	○	○	○	○	○
Back/spine	○	○	○	○	○	○	○	○
Stomach/chest	○	○	○	○	○	○	○	○
Arm/elbow/wrist/hand/fingers	○	○	○	○	○	○	○	○
Shoulder incl. clavicle	○	○	○	○	○	○	○	○
Neck	○	○	○	○	○	○	○	○
Head	○	○	○	○	○	○	○	○
2 Injury type								
Contusion	○	○	○	○	○	○	○	○
Sprain incl. rupture (joint/ligament)	○	○	○	○	○	○	○	○
Strain (muscle)	○	○	○	○	○	○	○	○
Fracture	○	○	○	○	○	○	○	○
Dislocation	○	○	○	○	○	○	○	○
Superficial skin lesion (abrasion)	○	○	○	○	○	○	○	○
Deep skin lesion (cut, laceration)	○	○	○	○	○	○	○	○
Overuse injury (gradual onset)	○	○	○	○	○	○	○	○
Other injury type	○	○	○	○	○	○	○	○
3 Contact with other player								
Yes	○	○	○	○	○	○	○	○
No	○	○	○	○	○	○	○	○
4 Expected absence from football								
Continued playing	○	○	○	○	○	○	○	○
Remainder of game	○	○	○	○	○	○	○	○
Out for 1-3 days	○	○	○	○	○	○	○	○
Out for 4-7 days	○	○	○	○	○	○	○	○
Out for 8-28 days	○	○	○	○	○	○	○	○
Out for 28+ days	○	○	○	○	○	○	○	○

Supplementary comments: