Oslo Sports Trauma
RESEARCH CENTER

Agnethe Nilstad

Injuries and risk factors in elite female football - Implications for screening and prevention

DISSERTATION FROM THE NORWEGIAN SCHOOL OF SPORT SCIENCES - 2014


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List of papers

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

I. Text messaging as a new method for injury registration in sports – A methodological study in elite female football. *Scand J Med Sci Sports* 2014: 24(1):243-249.

II. Risk factors for lower extremity injuries in elite female soccer players. *Am J Sports Med* 2014: 42(4):940-948.

III. Physiotherapists can identify female football players with high knee valgus angles during vertical drop jumps using real-time observational screening. *J Orthop Sports Phys Ther* 2014: 44(5):358-365.

IV. Anatomical and neuromuscular determinants for peak knee valgus angles in vertical drop jumps. *Submitted to Am J Sports Med.*

Abbreviations

ACL	Anterior cruciate ligament
BMI	Body mass index
CI	Confidence interval
Cm	Centimeter
GJL	Generalized joint laxity
Hz	Hertz
HR	Heart rate
ICC	Intraclass correlation coefficient
kg	Kilogram
mm	Millimeter
Nm	Newton meter
OA	Osteoarthritis
OR	Odds ratio
OSTRC	Oslo Sports Trauma Research Center
SD	Standard deviation
SMS	Short Message Service, also known as text messaging
2D	Two-dimensional
3D	Three-dimensional

Summary

Background

Previous reports have documented that lower extremity injuries account for 60-85% of all time-loss injuries in female football. However, methodological differences have led to significant discrepancies in injury patterns reported. Furthermore, few studies have investigated lower extremity risk factors in female players, and there is a need for reliable screening tools to identify the risk of injury. The aims of this thesis were therefore to validate a novel method for injury registration in sports and investigate risk factors for lower extremity injuries, as well as to further assess screening tools used to identify athletes at risk.

Methods

We invited all female football players in the Norwegian elite league to preseason screening tests prior to the 2009 competitive season with the aim of investigating risk factors for non-contact anterior cruciate ligament (ACL) injuries. New players in the elite league were included every year during the subsequent seasons (2010-13). We used a set of comprehensive screening tests to evaluate potential biomechanical, neuromuscular and anatomical risk factors, and each player spent about 7 h to completing all screening tests during one day of testing. In addition, we invited players included during the first year of screening (2009) to complete individual prospective injury registrations throughout the 2009 competitive football season. Training and match exposure, as well as all time-loss injuries, were collected using text messaging (SMS-tracking) with weekly reports throughout the season. Concurrent with the individual registration, the medical staff for each team also recorded injuries and exposure, and we validated the new method versus traditional medical staff recordings (Paper I). We investigated risk factors for lower extremity injuries among players providing complete data from the pre-season screening tests in 2009 and the prospective SMS injury registration throughout the subsequent football season (Paper II). Two of our screening tests were compared to assess whether real-time observational screening can be used to identify players with high knee valgus angles and abduction moments during a drop jump landing measured with three-dimensional (3D) motion analysis (Paper III). To investigate determinants for knee valgus angles in the vertical drop jump task, we assessed the combined effect of anatomical and neuromuscular characteristics on peak knee valgus angles for players included from 2009 through 2012 (Paper IV).

Main results

There was a substantial discrepancy between individual registrations and traditional team medical staff registrations, with the medical staff missing more than half of the injuries occurring during the season. Furthermore, they captured only 50% of the severe injuries leading to absence for more than 4 weeks that were reported by the players (Paper I). For players providing complete results from the 2009 risk factor screening and the subsequent individual injury registration (n=173), 107 of these sustained 171 injuries in total. Greater body mass index (BMI) was the only factor significantly associated with new lower extremity injuries (OR 1.51, CI 1.21-1.90, $p=0.001$). Greater BMI was associated with new thigh injuries, lower knee valgus angles in a drop jump landing was associated with new ankle injuries, a previous knee injury with new lower leg and foot injuries, whereas none of the factors influenced the risk of new knee injuries in the multivariate regression model (Paper II). During a drop jump landing, players subjectively scored with poor knee control displayed higher mean peak knee valgus angles compared to players scored with good control ($10.3 \pm 3.4°$ versus $1.9 \pm 4.3°$, $p \leq 0.001$). Three physioterapists assessed the players concurrently, and there was good agreement between raters, with percentage agreement and Kappa coefficients ranging from 70% to 95% and 0.52 to 0.92, respectively (Paper III). When further investigating knee valgus angles in a drop jump landing, we identified greater player height and static knee valgus angles, and lower hip abductor strength as being significantly associated with peak knee valgus angles. However, the multiple regression model only explained 13% of the variance in the observed peak knee valgus angles (Paper IV).

Perspectives

Based on the current studies, we recommend future investigations to conduct injury registrations in team sports using individual weekly reports rather than monthly medical staff registrations. To reduce lower extremity injury rates in female football, our findings suggest that BMI, knee valgus during drop jumps and previous knee injuries are relevant factors. Furthermore, athlete screenings are essential to identify players at risk of injury, and we have shown that a real-time observational screening test can be used to identify athletes with high knee valgus angles during drop jumps. This simple and efficient test can therefore be used for large-scale screenings of athletes. Finally, a better understanding of the underlying factors that contribute to knee valgus is of importance to identify athletes who may benefit from injury prevention training. Based on our findings, further investigations of potential determinants for knee valgus are therefore needed.

Introduction

Football is one of the most popular sports worldwide, with around 270 million players participating, and the number of female players is growing rapidly (FIFA, 2007). The Football Association of Norway (NFF) consists of 27 532 teams, counting 364 940 players in total, of which 105 595 are female players (Haavik, 2013). In addition to the increasing number of female players, there seems to have been an increase in playing dynamics, as well as more distinct athletics of the players (Faude et al., 2005).

The physical demands of elite female football

Football is characterized by the ability to repeat high-intensity work while maintaining efficient execution of skills when passing, dribbling, shooting and possessing the ball (Mohr et al., 2003). Thus, performance in football is dependent upon many factors, including physiological, technical, tactical, and mental characteristics. During a regular 90-min match, elite female football players run about 9-11 km in total (Krustrup et al., 2005; Mohr et al., 2008). Their average heart rate (HR) during match play is estimated to be 86-87% of maximum HR, with the peak HR corresponding to 97-98% (Krustrup et al., 2005; Krustrup et al., 2010). During match play, elite female players conduct more than 1300 changes in activity, corresponding to an activity change every 4 s (Mohr et al., 2008). Moreover, they seem to perform less high-intensity running and repeated sprints towards the end (Krustrup et al., 2005; Mohr et al., 2008; Krustrup et al., 2010). The significant decrease in high-intensity running during the final 15 min of a match compared to the first 15 min indicate that perturbations in work rate during the final phase of the game may be caused by game-induced fatigue.

Injuries in female football

Playing football, however, is accompanied by an increased risk of musculoskeletal injury (Engström et al., 1991; Östenberg & Roos, 2000; Giza et al., 2005; Faude et al., 2005; Jacobson & Tegner, 2007; Tegnander et al., 2008; Le Gall et al., 2008; Hägglund et al., 2009; Gaulrapp et al., 2010), including subsequent short- and long-term consequences. Hence, the development of injury prevention protocols is a necessity to reduce the rate of injuries in football.

Injury surveillance is a key risk management tool, and establishing reliable and feasible registration systems is a necessary step towards identifying risk factors and implementing preventive strategies. The overall long-term aim of sports medicine research is to prevent injuries. Traditionally, injury prevention research has been referred to as a four-step systematic sequence, first described by van Mechelen et al (1992). The first step involves defining the magnitude of the problem by identifying the incidence and severity of injuries through injury surveillance. The second step is to identify the injury mechanisms and risk factors for injury, and thus describe how and why the injuries occur. The third step involves developing and introducing a prevention strategy that is likely to reduce the number of injuries in the population at risk. Finally, the effect of the prevention strategy is assessed by repeating the first step. This four-step sequence has later been expanded by Finch (2006), who introduced a 6-stage model taking into account the importance of the implementation process into a real-world situation (Table 1).

Table 1. The Translating Research into Injury Prevention Practice (TRIPP) framework for research leading into real-world sports injury prevention. Derived and modified from Finch (2006).

Model stage	TRIPP
1	Injury surveillance using valid and reliable methodologies
2	Etiological research to elucidate risk factors and mechanisms of injury
3	Develop preventive measures
4	Intervention efficacy assessment under "ideal conditions"
5	Describe intervention context to inform implementation strategies
6	Evaluate effectiveness of preventive measures in the implementation context

Injury definition

A sports injury, whether acute or resulting from overuse, can be defined as "any trauma that occurs in relation to sport activities" (van Mechelen et al., 1992). An acute injury can be described as an injury resulting from a specific, identifiable event, whereas an overuse injury is traditionally defined as an injury caused by repetitive microtrauma, without a single identifiable event responsible for the injury (Fuller et al., 2006). However, there are numerous descriptions of overuse injury in the literature with no standard definition (Bahr, 2009).

It is well known that variations in injury definitions and methodology may create substantial discrepancies in the results and conclusions obtained from sports injury surveillance. As a consequence, a consensus statement on the definition of injury and data collection procedures in football was developed in 2006 (Fuller et al., 2006). 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". A "time-loss injury" referred to "an injury resulting in a player being unable to take a full part in future football training or match play", whereas a "medical attention" injury was defined as "an injury that results in a player receiving medical attention" (Fuller et al., 2006).

The choice of injury definition will influence the rate of injury reported, as players will not always seek medical attention for their complaints and even fewer cases will result in time-loss injuries. The time-loss injury is highly dependent on training frequency, as an injury leading to one day of absence from training may not be recorded if there are only three training sessions a week. In this case, minor injuries may be missed from the registration. Furthermore, the time-loss definition is also sports dependent; i.e. a football player can continue training with a broken finger, whereas a handball player would be prevented from full participation in training and match play in this case. As such, when using the time-loss definition, minor injuries may be missed, as they will not necessarily lead to absence from training, whereas a physical-complaint definition would capture this injury. We can therefore expect that the physical-complaint definition would yield a higher injury rate than the time-loss definition (Bahr, 2009).

It has been stated that the time-loss definition is not suitable for the reporting of overuse injuries, as these injuries have a gradual onset and the classification of injury may not be obvious in all cases. However, if the process exceeds the tissue`s ability to repair and adapt it might result in a noticeable overuse injury with corresponding symptoms and absence from activity, and thus captured through a time-loss definition (Bahr, 2009). Nevertheless, overuse injuries may represent as much of a problem as acute injuries in sports, and the true burden of these injuries may not be fully known until we have valid and reliable methods to record them.

The severity of injuries is commonly defined according to the duration of absence (number of days) from training and match play. The definition is therefore based on "the number of days that have elapsed from the date of injury to the date of the player`s return to full participation on team training and availability for match selection" (Fuller et al., 2006). The severity of time-loss injuries has been classified as slight (0 days), minimal (1-3 days), moderate (8-28 days) and severe (>28 days).

Injury registration methods

The rate of injuries in sports is not only dependent on the injury definition, but also the method used to record injuries (Junge & Dvorak, 2000; Fuller et al., 2006). Over the last decades, variations in injury definitions and registration methods used to describe injury patterns in sports have created substantial discrepancies in injury rates reported, and thus the conclusions drawn (Junge & Dvorak, 2000; Fuller et al., 2006; Bjørneboe et al., 2011; Flørenes et al., 2011; Clarsen et al., 2013a). Furthermore, these discrepancies have lead to difficulties comparing injury rates between studies. According to the 2006 consensus statement (Fuller et al., 2006), studies should be of a prospective cohort design to minimize potential errors related to recall bias, which is a problem associated with retrospective studies. In a study from Czech football (Junge & Dvorak, 2000), the authors found that retrospective questionnaires completed by the players at the end of the season only captured 1/3 of the injuries recorded prospectively by a physician visiting the teams once a week during the 1-year follow-up.

Although registrations conducted by a member of the medical staff are preferable, this is not necessarily the best registration method in all settings. A study from male professional football found that prospective injury surveillance by team medical staff underestimated the incidence of time-loss injuries by at least one-fifth compared to player interviews (Bjørneboe et al., 2011). Interestingly, similar findings were reported among World Cup alpine skiers, where 91% of the injuries were identified through retrospective athlete interviews compared to 47% by team medical staff registrations (Flørenes et al., 2011). The quality of data collected is dependent on the completeness and accuracy of injury registrations, and whether individual player reports or traditional medical staff registrations would provide the most complete picture of injuries in female football is not known. In Paper I we therefore aimed to address this question by introducing and validating a novel method for injury registration in sports.

Injury incidence

The risk of injury is traditionally expressed as injury incidence, referring to the number of new cases in a defined population during the course of a given time period. Injury incidence is commonly reported as the number of injuries per 1000 hours of player exposure.

Playing football is associated with high injury risk, but despite the increasing number of female players, relatively few studies have addressed injury patterns in female football. Based on previous reports, the injury incidence among female senior players ranges between 1 to 7 injuries per 1000 hours of training, and 13 to 24 per 1000 hours of match play (Engström et al., 1991; Östenberg & Roos, 2000; Giza et al., 2005; Faude et al., 2005; Jacobson & Tegner, 2007; Tegnander et al., 2008; Le Gall et al., 2008; Hägglund et al., 2009; Gaulrapp et al., 2010). These studies have documented that the injury incidence is substantially higher during match play, with the highest incidence (24 per 1000 hours) reported among Swedish elite players (Engstrom et al., 1991). Similarly, in German elite players (Giza et al., 2005) an incidence of 23.3 acute injuries per 1000 match hours have been reported during one football season. In the Norwegian female elite league, the corresponding incidence was 23.6 for match injuries in the 2006 football season (Tegnander et al., 2008) (Table 2). In Paper I we have provided new data on the injury incidence in Norwegian elite female football players.

Table 2. Prospective epidemiological studies on injury incidence in senior elite and amateur female football

Reference (year)	Participants	Injury definition	Injury recording, follow-up	# injuries	Injury incidence (#/1000 h)		
					Match	Training	Total
Engström et al. (1991)	Elite (n=41) 21 years	Time loss	Medical students, 12 months	78	24.0	7.0	12.0
Östenberg & Roos (2000)	Amateur (n=123) 14-39 years	Time loss	Physiotherapists, 7 months	65	14.3	3.7	6.6
Söderman et al. (2000)	Amateur (n=146) 20-25 years	Time loss	Coaches and players (diagnosed by physiotherapist), 7 months	80	10.0*	1.3*	5.5*
Giza et al. (2005)	Elite (n=202) Age n/a	Insurance claim	Team physician, 2 x 5 months	173	12.6	1.2	1.9
Faude et al. (2005)	Elite (n=115) 17-27 years	Time loss	Physiotherapist and team physician, 11 months	241	23.3*	2.8*	6.8*
Jacobson & Tegner (2007)	Elite (n=269) 16-36 years	Time loss	Coaches (telephone injury assessment by authors), 10 months	237	13.9	2.7	4.6
Hägglund et al. (2008)	Elite (n=228) 15-41 years	Time loss	Physiotherapist and team physician, 10 months	299	16.1	3.8	5.5
Tegnander et al. (2008)	Elite (n=181) 17-34 years	Time loss	Physiotherapist, 7 months	189	23.6*	3.1*	6.2*
Gaulrapp et al. (2010)	Elite (n=254) 16-35 years	Time loss	Team physicians, 12 months	246	18.5	1.4	3.3

**Only acute injuries were reported*

Injury patterns

The majority of injuries are acute, and injuries to the lower extremities are most common, accounting for 60% to 85% of all time-loss injuries among senior female players (Engström et al., 1991; Söderman et al., 2001a; Faude et al., 2005; Giza et al., 2005; Jacobson & Tegner, 2007; Hägglund et al., 2009; Gaulrapp et al., 2010). Previous reports have documented that the knee is the body part most frequently injured, accounting for 16% to 32% of all time-loss injuries. With regards to injury type, most injuries affect muscles, tendons or ligament/joint structures. Ligament sprains typically result in long absences from sports and represent 19% to 46% of time-loss injuries in senior female players (Engström et al., 1991; Söderman et al., 2001a; Faude et al., 2005; Giza et al., 2005; Jacobson & Tegner, 2007; Hägglund et al., 2009; Gaulrapp et al., 2010). One of the aims of Paper I was to describe injury patterns among Norwegian elite female football players.

Overuse injuries have traditionally received little attention in the sports injury literature, although they are common among football players. One explanation for the lack of knowledge is that their typical presentation and characteristics make them difficult to record in epidemiological studies (Bahr, 2009). Symptoms such as pain and reduced function often appear gradually and players are likely to continue to train and compete with these symptoms without time lost from sport. The ability of validly and reliably record overuse conditions therefore presents a problem, largely due to the fact that athletes often continue to train and compete despite the existence of overuse problems. Overuse injuries may therefore represent more of a problem in senior female football than what has been suggested from previous reports.

ACL injuries

Injuries to the ACL are of particular concern in female athletes (Agel et al., 2005; Prodromos et al., 2007; Waldén et al., 2010; Waldén et al., 2011). The ACL is an intracapsular, extrasynovial ligament of the knee and a primary restraint to anterior displacement of the tibia relative to the femur (Figure 1). It is also a secondary restraint to knee rotation and frontal plane angulations

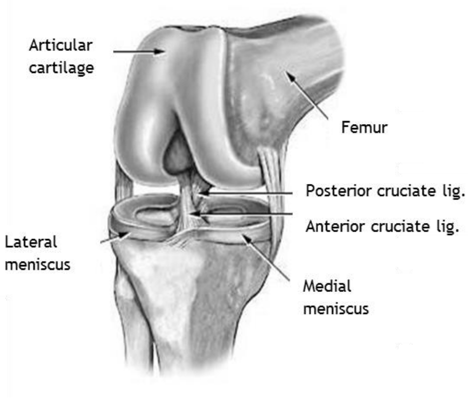

Figure 1. Anatomy of the knee and location of the ACL.

(Beynnon et al., 2005). The ACL is therefore important for knee stabilization during sport activities. This ligament consists of two bundles; the anteriomedial bundle located proximally and anteriorly in the femoral intercondylar notch, and the posterolateral bundle originating in the distal and posterior aspect (Petersen & Zantop, 2007).

In football, ACL injuries constitute about 5% of all time-loss injuries, regardless of playing level, with an annual prevalence of between 0.5% and 6% in females (Waldén et al., 2011). In jumping, cutting and pivoting sports such as football, basketball and volleyball, females are suggested to have a 4-6 times higher ACL injury risk compared to their male counterparts (Arendt et al., 1999; Agel et al., 2005; Mihata et al., 2006; Renstrom et al., 2008; Waldén et al., 2010). However, considering football players only, female players in Scandinavia seem to have a 2-3 times higher risk of suffering an ACL injury compared to males (Waldén et al., 2011). Furthermore, females appear to rupture their ACL at an earlier age than do males (Waldén et al., 2010; Waldén et al., 2011), and it has been suggested that the risk is especially high in adolescent female players competing at the adult level (Söderman et al., 2002).

An ACL injury can be devastating for the athlete and constitutes serious short and long-term consequences in terms of time lost from sports participation and long rehabilitation time, as well as an increased risk for early development of knee osteoarthritis (von Porat et al., 2004; Oiestad et al., 2009; Ajuied et al., 2013). Furthermore, the symptoms experienced after an injury may even force the athlete to stop playing football within few years (Söderman et al., 2002). The high incidence and documented short- and long-term consequences of injury emphasize the importance of injury prevention and explain the attention ACL injuries have received in injury prevention research.

Injury mechanisms

Establishing the etiology and mechanisms of injuries is a critical step in the injury prevention research model. This includes obtaining information on why an athlete may be at risk in a given situation, the risk factors, and how the injuries happen, the injury mechanisms (Bahr & Krosshaug, 2005). Taking the multifactorial nature of sports injuries into account, Meeuwisse (1994) developed a model describing how an injury likely results from a complex interaction between intrinsic and extrinsic risk factors. Within this framework, the inciting event is described as the final link in the chain causing an injury. This model was later modified and expanded by Bahr and Krosshaug (2005), accounting for the events leading to the injury situation (Figure 2). A complete description of the mechanisms of a specific injury should preferably include aspects of the specific sport situation, a gross description of the athletes behaviour and movement, and detailed information on biomechanical characteristics of anatomical structures (Bahr & Krosshaug, 2005).

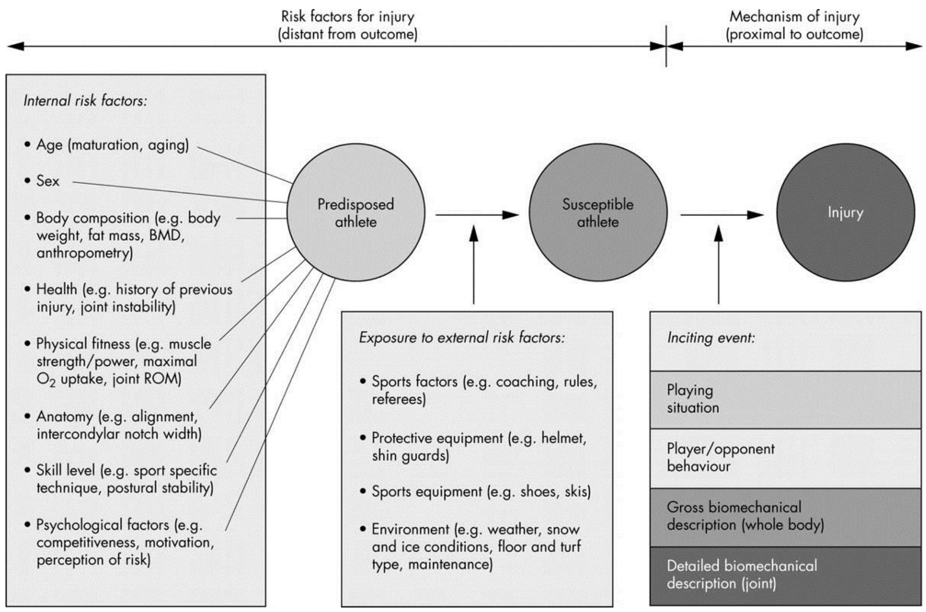

Figure 2. A comprehensive model for injury causation. The figure is retrieved from Bahr & Krosshaug (2005), developed from the epidemiological model by Meeuwisse (1994).

In pivoting sports such as football, the vast majority of investigations on injury mechanisms have focused on the ACL injury, both due to the higher risk in females and the consequenses of injury. Visual inspections of videos from injury situations have shown that ACL injuries typically occur during unilateral loading in sidestep cutting and single-leg landings, without any contact with another player (Boden et al., 2000; Olsen et al., 2004; Krosshaug et al., 2007; Boden et al., 2009; Hewett et al., 2009). A common pattern reported from video analyses is that the athlete is out of balance at the time of injury, with a lateral positioning of the center of mass and a valgus collapse of the knee (Boden et al., 2000; Olsen et al., 2004; Krosshaug et al., 2007; Boden et al., 2009; Hewett et al., 2009).

Two main theories have been proposed and discussed the past decades: the quadriceps drawer theory and the valgus loading theory. The quadriceps drawer theory was introduced by DeMorat et al (2004), and is based on the underlying premise that the pull of the patellar tendon has an anterior component that may strain the ACL and cause injury alone. They used cadaver models and applied a simulated quadriceps loading of 4500 N, causing an ACL rupture in six of the 13 specimen included, supporting the quadriceps drawer theory. In contrast, McLean et al. (2004) used motion analysis and mathematical modeling to simulate injury during side-step cutting maneuvers and found knee valgus loads exceeding values high enough to rupture the ACL. The authors concluded that an ACL injury cannot be explained by motion in the sagittal plane only, and proposed that valgus loading is a more likely injury mechanism. Valgus motion has also been observed in video analyses of ACL injuries (Olsen et al., 2004; Krosshaug et al., 2007), which further supports the valgus loading theory. However, whether the observed valgus is a factor causing the ACL rupture or the result of a torn ACL remains to be explained.

Koga et al. (2010) described 3D kinematics and kinetics for ten noncontact ACL injuries in female team handball and basketball using a model-based image-matching technique (Krosshaug & Bahr, 2005). This method was found to be superior to visual video inspections, as it provides more robust estimates of joint kinematics at the time of injury by matching an animated kinematic model to video recordings from different angles. Koga (2010) reported consistent kinematic patterns in all ten injury cases: a valgus motion in combination with internal tibial rotation occurred within 40 ms after initial contact, followed by external rotation of the tibia. Based on these findings, they concluded that valgus loading in combination with tibial internal rotation are contributing factors to an ACL injury, and that the sudden external rotation likely occurs after the ACL has ruptured (Figure 3). It was, however, unclear whether quadriceps drawer or joint compression contributed to injury in these cases.

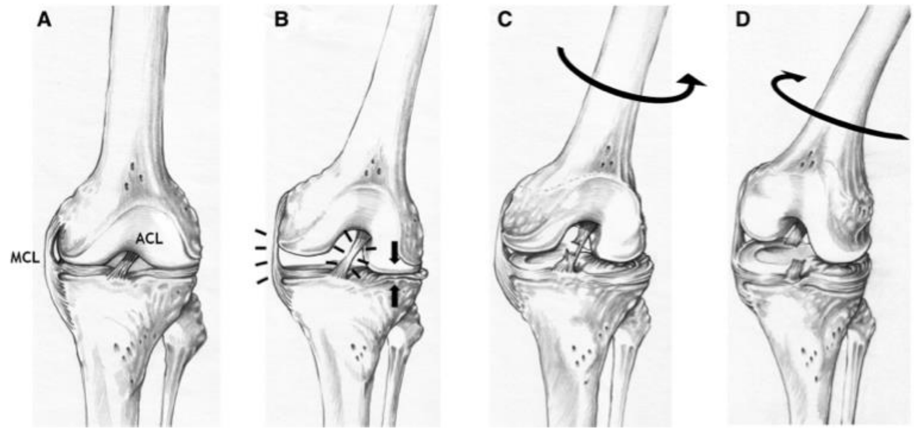

Figure 3. Mechanism of ACL injury as suggested by Koga (2010). Valgus loading leads to tightening of the medial collateral ligament and compression of the lateral joint compartment (B). The compressive load and the anterior force vector will cause a discplacement of the femur relative to the tibia, the lateral femur condyle shifts posteriorly with an anterior translation and internal rotation of the tibia, causing ACL rupture (C). When the ACL is torn, the medial femoral condyle moves posteriorly, resulting in external rotation of the tibia (D).

Findings from clinical imaging and arthroscopic studies support a multiplanar mechanism. Bone bruises on the lateral femoral condyle or posterolateral parts of the tibia plateau are described in the majority of MRI investigations after injury (Speer et al., 1992; Spindler & Wright, 2008; Viskontas et al., 2008). These clinical findings indicate that a knee valgus mechanism is likely, leading to lateral compression of the femoral and tibial condyles. Furthermore, a greater posterior tibial slope has been identified in ACL-injured subjects compared to controls, which may predispose them to anterior translation of the tibia during impact and therefore strain the ACL (Brandon et al., 2006; Hashemi et al., 2010).

With regards to the mechanisms for ACL injury in female football players in particular, there is limited documentation available. Two reports, one from an injury surveillance system in American collegiate football (soccer) (Agel et al., 2005), and another from a Danish outpatient sports clinic (Faunø & Wulff, 2006), confirm that non-contact injuries also dominate among female football players. Furthermore, the injuries typically occur during a change of direction or a cutting maneuver, during deceleration, in the landing after a jump or when pivoting with the foot fixed on the ground (Boden et al., 2000; Faunø & Wulff, 2006).

Injury prevention

Following the increased awareness of injuries in football, as well as of the high incidence of ACL injuries in female athletes, there has been an equivalent increase in the research on injury prevention. Several investigations have evaluated injury prevention strategies in female football players, most of them targeting adolescents (Hewett et al., 1999; Söderman et al., 2000; Heidt et al., 2000; Mandelbaum et al., 2005; Gilchrist et al., 2008; Soligard et al., 2008; Steffen et al., 2008b; Emery & Meeuwisse, 2010; Kiani et al., 2010; Waldén et al., 2012; Steffen et al., 2013). In a randomized controlled trial among Swedish female adolescent football players, Waldén et al. (2012) documented that a 15-min neuromuscular warm-up program reduced the overall rate of ACL injury by 64%. They also found a preventive effect for severe knee injuries and for any acute knee injury in players completing the prevention program at least once a week. Moreover, their analyses showed that the number needed to treat was 14, meaning that for every 14 players who receive the warm-up program one less ACL injury would occur per 1000 playing hours.

Steffen et al. (2013) investigated the effect of a 20-min neuromuscular prevention program on injuries occurring during football activity, as well as the effect on specific performance variables, in youth female football players. Their results identified reduced injury rates and increased performance in players using the prevention program for 18 weeks. Furthermore, players reporting high compliance with the intervention demonstrated better functional balance and a 72% reduction in injury risk compared to players with less compliance. Similarily, Soligard et al. (2008) demonstrated that severe injuries were reduced by 50% and the risk of knee injuries was significantly lower in youth female football players completing a 20-min neuromuscular warm-up program twice a week. Common components among these programs are exercises focusing on core stability, balance, landing technique and proper knee alignment, which also are features of previous successful intervention studies (Myklebust et al., 2003; Olsen et al., 2005).

Similar trends have been reported from non-randomized investigations. In a study by Kiani et al. (2010), a cohort of 1506 adolescent female football players were divided into an intervention and a control group and followed prospectively during one season. The players in the intervention group used a warm-up program including balance, strength and core stability exercises with the aim of improving motion patterns to reduce knee joint stress. These players experienced a 77% and 90% reduction of knee injuries and non-contact knee injuries, respectively. Corresponding findings were reported by Mandelbaum et al. (2005) in an investigation on the effect of a multi-component warm-up program on knee injury rates among adolescent female football players.

The program consisted of warm-up, exercises for flexibility, strength, plyometrics and agility, and they were followed for two seasons. During the first season, they found an 88% reduction of ACL injuries in the intervention group, and a 74% reduction during the second season. In another study, Hewett et al. (1999) prospectively followed a cohort of 829 female team sport athletes, of whom 290 were football players, with the aim of reducing the risk of knee injuries. In their non-randomized study, the athletes were allocated into an intervention group receiving neuromuscular training, and a control group, and the groups were followed through one season. Athletes in the intervention group experienced a decrease in non-contact knee injuries. In a similar study among adolescent female football players, Heidt et al. (2000) investigated the effect of a pre-season multi-component training program. After 7 weeks of training, they were followed over one year and there were significantly fewer injuries in the training group. However, despite of their indication of positive effects of neuromuscular training, these findings should be interpreted with caution due to the non-randomized design.

In contrast to these studies, Söderman et al. (2000) found no effect of balance board training on lower extremity injuries in senior female football players. The results from this randomized controlled trial showed no differences between the intervention and control group, neither for the number, incidence or type of injuries. However, their statistical power was low, as was compliance with the training, which also influences the conclusions drawn.

Nevertheless, existing reports have revealed promising findings, suggesting that knee injuries in female football players can be prevented. Based on these investigations, it seems that neuromuscular training programs combining strength, balance, core stability and focus on proper knee alignment are effective.

Risk factors for lower extremity injury

Although targeted training programs aiming to improve strength, stability and proper knee alignment have successfully reduced the rate of knee injuries in female football, the identification of risk factors may provide a more complete understanding of why some players sustain injuries whilst others do not.

A variable associated with injury is termed a risk factor. Traditionally, we classify the risk factors as being either intrinsic or extrinsic (Meeuwisse, 1994). Intrinsic risk factors are individual characteristics that may predispose an athlete to sustaining an injury. Extrinsic risk factors are independent of the injured athlete and are principally related to the type of activity during the incident of injury. These factors may contribute to injury risk, leaving a person more susceptible to injury. Risk factors can also be divided into modifiable and non-modifiable factors (Emery et al., 2005). Modifiable risk factors refer to those that can be altered by injury prevention strategies, whereas a non-modifiable factor cannot be changed. However, a non-modifiable factor may still contribute to injury risk, by influencing the relationship between modifiable risk factors and injury. Nevertheless, it is clearly important to study factors that are potentially modifiable through physical training such as strength, balance, or flexibility, or behavioral approaches.

There is limited evidence with regards to risk factors for injuries in female football players (Table 3). Only three studies have investigated risk factors for injuries in senior female players (Östenberg & Roos, 2000; Söderman et al., 2001b; Faude et al., 2006), and only one of these included elite players (Faude et al., 2006). Data on injury risk in youth female football players are also lacking, as only few studies have been conducted (Emery et al., 2005; Steffen et al., 2008a; Steffen et al., 2009; Soligard et al., 2010b). In the following sections, potential injury risk factors in female football players will be discussed.

Table 3. Studies investigating intrinsic risk factors for injuries in senior and youth female football players

Reference (year)	Follow-up	Participants	Risk factor assessment	Outcome	Statistics	# Injuries	Risk factors identified
Senior females							
Östenberg & Roos (2000)	1 season	N=123 Age 20.7 ±5 yrs 5 levels	Quadriceps/hamstrings strength, single-leg-hop, square-hop, vertical jump, BMI, GJL, fitness tests	All injuries	Multiple logistic regression	65	↑GJL (OR 5.3) ↑square-hop performance (OR 4.3) Age >25 years (OR 3.7)
Söderman et al. (2000)	1 season	N=146 Age 20.6 ±5 yrs 2nd-3rd division	Age, anatomy, joint laxity, flexibility, quadriceps/hamstrings strength, postural sway, previous injuries, football exposure	Lower-ex injuries	Multiple logistic regression	80	↑GJL (OR 3.1)[a] ↑knee laxity (OR 3.8) ↓postural sway (OR 0.3) ↓H:Q ratio (OR 0.9) ↑football exposure (OR 1.6)
Faude et al. (2005)	1 season	N=143 Age 22.4 ±5 yrs Elite	Anthropometric measurements, previous injury, football exposure, playing position, limb dominance	All injuries	*t*-tests χ^2	216	Body height >175cm ↑body weight Previous ACL injury[b] (OR 5.2) Defenders and strikers More injuries in dominant leg
Youth females							
Emery et al. (2005)	1 season	N=317; ♀=164 12-18 yrs	Anthropometric measurements, previous injuries, dynamic balance, vertical jump, 20-m shuttle run	Lower-ex injuries	χ^2	39	Age <14 yrs (RR 3.3) Previous injury (RR 1.7)[c]
Steffen et al. (2008)	1 season	N=1430 14-16 yrs	Questionnaire assessing previous lower-ex injuries, FAOS, KOOS	Lower-ex injuries	Poisson regression	380	Previous injury (OR 1.9), ↑risk for additional injury (RR 1.1) ↑participation (RR 1.1 per year) ↓ankle/knee function (RR 1.7/3.2)
Steffen et al. (2009)	1 season	N=1430 14-16 yrs	Questionnaires assessing goal orientation, motivational climate, life stressors and anxiety	All injuries	Poisson regression	380	↑perception of life stress (OR 1.7) and mastery climate (OR 1.3)
Soligard et al. (2010)	1 season	N=1034 13-17 yrs	Questionnaire assessing technical, tactical and physiological attributes	All injuries	Cox regression	259	↑technical skills (RR 1.5 to 1.8) ↑tactical skills (RR 1.6 to 1.8) ↑muscle strength (RR 1.6)

OR, odds ratio; RR, relative risk; BMI, body mass index; GJL, generalized joint laxity, H:Q ratio, hamstrings-to-quadriceps ratio; ACL, anterior cruciate ligament; FAOS, Foot and Ankle Outcome Score; KOOS, Knee and Osteoarthritis Outcome Score. [a]*Univariate analysis only,* [b]*Risk for new ACL injury,* [c]*Females and males in combination*

Intrinsic risk factors

Age

With regards to age as a potential risk factor for injury, there are conflicting findings and no consensus in the literature. In an investigation among Swedish senior females, Östenberg & Roos (2000) followed 123 players during one football season, and higher age was found to increase injury risk. Players being older than 25 years were more likely to sustain an injury than younger players. In contrast, Söderman et al. (2001b) found no association between age and injury risk in senior female players. Conflicting results have also been reported from studies among youth female players. An 8-year study among junior elite females (Le Gall et al., 2008) found greater risk of injury in the youngest group of players (under age 15) compared with the oldest group (under 19). In contrast, Emery et al. (2005) demonstrated lower injury risk in the older age groups (under 18) compared to the younger groups (under 14), whereas another study found no association between age and injury risk (Steffen et al., 2008a).

Anthropometric characteristics

Anthropometric characteristics, such as height, body mass or body mass index (BMI), have been suggested as potential predictors for new lower extremity injuries, but the results are conflicting. Faude et al. (2006) assessed risk factors for injuries in German elite female football players and identified an increased injury risk for taller players, defined as height above 175 cm, as well as for players with greater body mass. In contrast, Östenberg & Roos (2000) found no relationship between height, body mass or BMI and new injuries. Similar findings have been reported among youth female players (Steffen et al., 2008a).

Joint laxity

Generalized joint laxity (GJL) refers to excessive joint mobility in more than one joint, typically referred to mobility in the fingers, thumbs, elbows, knees and the trunk/hips during forward flexion with the knees extended (Beighton et al., 1973). Söderman et al. (2001b) demonstrated a significantly increased risk of traumatic lower extremity injuries in senior female players with increased knee hyperextension and GJL. However, the number of injuries was too small to analyse the potential associations for specific diagnoses separately. Similar findings were reported among Swedish senior players, where GJL was significantly associated with new injuries

(Östenberg & Roos, 2000). Current findings therefore suggest that greater joint laxity is associated with increased likelihood of injury in female players.

Neuromuscular factors

To date, the effect of muscle strength or muscular imbalances on injury risk has not been investigated sufficiently in female football players. Only one study (Söderman et al., 2001b) assessed this potential relationship in senior players and found that a low concentric hamstring-to-quadriceps (H:Q) ratio was associated with new acute lower extremity injuries. Furthermore, in the same investigation a high H:Q ratio was found to increase the risk of overuse injury. Corresponding findings have been reported in female collegiate players (Knapik et al., 1991), where a H:Q ratio of less than 0.75 or side-to-side imbalances in knee flexor strength was associated with increased lower extremity injury risk.

Neuromuscular control and dynamic balance are factors suggested to be associated with injury risk. Östenberg & Roos (2000) documented that senior players with high performance on a functional square-hop test were more likely to sustain an injury compared to players with poor test scores. Similar findings were reported by Söderman et al. (2001b), who demonstrated a higher rate of lower extremity injuries in players displaying low postural sway, and thus good balance, on a single-leg balance test. In contrast, Emery et al. (2005) found no association between dynamic balance and injury risk among youth female players. To what extent neuromuscular control or performance on a balance test will influence the risk of injury is therefore not fully understood.

Leg dominance

For a football player, different demands with regards to the dominant and non-dominant leg during play may influence intrinsic properties such as strength and balance, and therefore also injury risk. In elite female players, Faude et al. (2006) found that significantly more injuries were reported in the dominant leg, defined as the preferred kicking leg. They observed a predominance of contact and ankle injuries, as well as ligament ruptures and contusions in the dominant leg. Neither of the other studies in female senior nor youth players assessed leg dominance in relation to injuries. Interestingly, when looking at ACL injuries only, Brophy et al. (2010) found that female football players were more likely to injure their supporting (non-dominant) leg. Among players visiting an outpatient orthopaedic clinic, two-thirds had suffered a non-contact ACL injury in their non-dominant leg, whereas male players tended to injure their dominant leg.

Previous injuries

A history of previous injury has typically been suggested as a risk factor for sustaining a new injury to the same location, likely due to a combination of incomplete rehabilitation and too early return to play. In senior female players, no association has been found between previous knee and ankle injuries and a new injury to the same location (Söderman et al., 2001b; Faude et al., 2006). However, in female elite football the risk of sustaining an ACL rupture was significantly increased in players reporting a previous ACL injury (Faude et al., 2006). In youth female players there seems to be an increased risk of a new injury with a previous injury in general (Emery et al., 2005), as well as a new injury to the same location for players with previous knee, ankle or groin injuries (Kucera et al., 2005; Steffen et al., 2008a). Furthermore, one study (Steffen et al., 2008a) found that the risk of injury increased with the number of previous injuries for each additional injury reported. Corresponding findings have consistently been reported in male professional football, where a previous injury has been identified as a risk factor for new injuries to the knee (Arnason et al., 2004; Hägglund et al., 2006; Waldén et al., 2006), ankle (Engebretsen et al., 2010a), hamstrings (Arnason et al., 2004; Engebretsen et al., 2010c) and groin (Arnason et al., 2004; Hägglund et al., 2006; Engebretsen et al., 2010b).

Psychological factors

In addition to individual physiological characteristics, psychological factors may also leave a player vulnerable to sustaining injuries. Life stressors, trait anxiety and daily hassle are factors found to increase injury risk in elite female and male football, explaining 24% of the variance (Ivarsson et al., 2013b). Similar findings have been reported in youth female and male players; life event stress, somatic trait anxiety, mistrust and ineffective coping were associated with increased injury risk (Johnson & Ivarsson, 2011). In another investigation among youth females, Steffen et al. (2009) found that players reporting previous stressful life events, as well as perceived mastery climate, were more likely to report injuries, whereas perception of success, competitive anxiety and stress coping skills had no influence of the occurrence of injury. Nevertheless, these findings suggest that psychological factors may contribute to injury risk in female football players.

Extrinsic risk factors

Exposure time

Volume and frequency of exercise as determined by the scheduling of training sessions and competitions are factors likely to influence injury risk. Accordingly, there is growing clinical concern regarding overscheduling in sports, especially among younger athletes, which may contribute to overuse injuries. The term overscheduling injury refers to an injury related to excessive planned physical activity without adequate time for rest and recovery, including between training sessions/competitions and consecutive days (Luke et al., 2011). Investigations among senior female players have reported conflicting results with regards to the association between exposure time and injury risk. Söderman et al. (2001b) found that high overall exposure significantly increased the risk of leg injury in senior players, whereas Faude et al. (2006) identified lower injury rates in players with higher match exposure. Furthermore, these authors reported an association between reduced training exposure and total exposure, and injuries. On the other hand, this finding could also be a consequence of injury and hence time lost from football participation. Another investigation among senior female players (Östenberg & Roos, 2000) found higher injury rates in players reporting a greater number of years playing football. In youth female players, no association has been found between sports participation and new injuries (Emery et al., 2005; Steffen et al., 2008a).

Playing surface

Grass is the traditional playing surface in football, but the development of artificial turfs with their inherent advantages, such as better resilience to various climatic conditions, lower maintenance costs and longer playing hours, have led to an increasing number of these pitches. Concerns have been raised that the injury risk may differ between natural grass and artificial turfs, but few studies have investigated this association in female players, and none among senior players. Fuller et al. (2007a; 2007b) followed female and male college football teams for two seasons and found no differences in the overall injury risk or severity of injuries. Similar findings were reported among youth females for overall injury risk (Steffen et al., 2007); however, the risk of severe match injuries was twice as high on artificial turf compared to natural grass. In youth tournament football, Soligard et al. (2010a) identified no differences in overall injury risk between playing surfaces, but a higher risk of injuries to the back, spine and shoulder on artificial turf.

In summary, there are few prospective studies investigating injury risk factors in female football players. Based on existing knowledge there are conflicting findings with regards to both intrinsic and extrinsic factors and the risk of injury in female football players. These studies suggest that greater joint laxity, muscular imbalances and high performance on balance tests, as well as the presence of life stressors, trait anxiety and performance climate on the team may increase injury risk in female football players. For age, anthropometric characteristics, previous injuries and exposure time there is no consensus as to whether these factors are associated with new injuries or not. Playing surface has not been found to influence injury risk in general, although playing on artificial turf seems to increase the risk of injuries to the trunk and upper extremities. However, some of these findings should be interpreted with caution due to methodological considerations such as small sample sizes and statistical methods used to assess potential risk factors. Thus, one aim of this thesis was to investigate intrinsic risk factors for lower extremity injuries in elite female football players by including a larger sample and using a multivariate statistical approach (Paper II).

Risk factors for ACL injury in females

The high incidence of ACL injuries in female athletes and the accompanying short- and long-term consequences have led to an increased focus on the identification of risk factors for injury. Consequently, several investigations have been initiated to assess potential risk factors among a variety of sports with varying number of participants, across different ages, using various study designs and measurement techniques.

Anatomy and ACL injury

An association between anatomical characteristics and ACL injury has been suggested, but there is no definitive evidence that such a relationship exists. Increased knee joint laxity and GJL has been found in females compared to males in an investigation among military cadets (Uhorchak et al., 2003), and was also found in cadets sustaining an ACL injury compared to non-injured controls (Uhorchak et al., 2003). In addition, a smaller femoral notch width and greater BMI was found in injured cadets compared to non-injured (Uhorchak et al., 2003). Other investigations have found an increased posterior slope of the tibia in ACL-injured subjects compared to controls (Brandon et al., 2006; Hashemi et al., 2010; Terauchi et al., 2011), suggesting that an anteriorly directed force on the tibia from the femur at landing will predispose an anterior glide of the tibia relative to the femur, which in turn may strain the ACL and increase the risk of rupture.

Increased foot pronation has also been proposed as a risk factor, as increased pronation of the foot may stress medial structures of the lower limb and alter biomechanics of the lower extremity, and therefore potentially increase injury risk. Greater foot pronation, measured by navicular drop, has been found in subjects with a history of an ACL tear compared to matched controls (Beckett et al., 1992; Woodford-Rogers et al., 1994; Loudon et al., 1996; Allen & Glasoe, 2000), supporting the concept that excessive foot pronation may contribute to ACL injury risk.

Hormones and ACL injury

It has been suggested that sex hormones may, in part, explain the observed gender differences in ACL injury rates. However, despite of a considerable research focus on the relationship between sex hormone fluctuations and ACL injury, the literature provides conflicting evidence. Among studies, there are disparities with regards to the phases of the menstrual cycle in which most injuries seem to occur: the follicular phase (Arendt et al., 2002; Slauterbeck et al., 2002; Myklebust et al., 2003; Ruedl et al., 2009), the ovulatory phase (Wojtys et al., 1998; Wojtys et al., 2002; Beynnon et al., 2006; Adachi et al., 2008) or the luteal phase (Möller Nielsen & Hammar, 1991). However, although a link may exist between hormone fluctuations and ACL injury, this potential association is difficult to determine due to methodological challenges and the need for long-term monitoring with day-to-day serum measurements of the population at risk.

Neuromuscular factors and ACL injury

Deficient neuromuscular control or muscle activity may predispose athletes to ACL injury. Zebis et al. (2009) screened 55 elite female football and handball players prior to their competitive seasons, of which five subsequently sustained an ACL rupture. They found significantly reduced preactivity of the medial hamstrings and higher preactivity of the vastus lateralis muscles in ACL-injured athletes compared to non-injured. Despite of the low number of injuries, the findings suggest that specific muscle activation patterns may contribute to ACL injury risk and that an upregulation of medial hamstrings activity could be of relevance in injury prevention protocols.

Previous research has also targeted core proprioception as a potential neuromuscular risk factor for injury. In a prospective cohort study, Zazulak et al. (2007a) investigated the effect of trunk displacement after a perturbation as a potential predictor of knee injury in 277 female and male athletes. The athletes were positioned in a multidirectional sudden force release apparatus, where a resisted force of 30% of maximum isometric exertion was released. Over a three-year period, six ACL injuries were confirmed (4 in females), and additionally 19 other knee injuries. Trunk displacement in any plane was greater in the injured athletes compared to non-injured, and this model predicted ACL injury risk with 83% sensitivity and 76% specificity. However, their limited sample size represents a major limitation and definite conclusions cannot be drawn.

Deficits in dynamic neuromuscular control in all planes of motion along the entire lower extremity kinetic chain may represent an important contributing factor to the observed gender differences in ACL injury rates. Decreased core proprioception was found to be related to knee ligament injury in female athletes in another study by Zazulak and co-workers (2007b). Core proprioception was measured in female and male collegiate athletes using an apparatus producing trunk perturbations. The females sustaining a knee ligament injury during the following three years displayed significant deficits in active proprioceptive repositioning compared to non-injured. Yet, one should keep in mind that only 25 injuries were included over a three-year follow-up, of which only 11 were sustained by females.

Knee valgus and ACL injury

Given the fact that the majority of ACL injuries in female athletes are non-contact injuries, and that they often occur during a cutting maneuver or a single-leg landing (Boden et al., 2000; Olsen et al., 2004; Krosshaug et al., 2007; Boden et al., 2009; Hewett et al., 2009), the majority of studies investigating potential biomechanical and neuromuscular risk factors in female athletes have assessed these factors during jump-landing tasks or cutting maneuvers.

In a prospective study by Hewett et al. (2005), a link was suggested between frontal plane biomechanics and the risk of ACL injury in female athletes. Using 3D motion analysis, they investigated knee kinematics and kinetics during a vertical drop jump task in 205 female football, basketball and volleyball players. Nine of the athletes subsequently sustained an ACL rupture, and these displayed significantly higher knee valgus angles and abduction moments compared to the 196 non-injured athletes. Injured athletes also demonstrated significant side-to-side differences in knee abduction moments, and these were 6.4 times higher than for non-injured. Furthermore, knee abduction moments were found to predict future ACL injury with a sensitivity and specificity of 78% and 73%, respectively. However, these findings are based on nine injury cases only, and no potential confounding factors were taken into account in their statistical analyses. Thus, the results must be interpreted accordingly.

Nevertheless, this investigation demonstrated that increased knee valgus angles and abduction moments during the impact phase of a drop jump task may be key contributors to ACL injury in female athletes. The authors suggested that the observed dynamic knee valgus could be a result of decreased neuromuscular control in the frontal plane, and therefore a potential target for injury prevention. Moreover, several investigations have demonstrated a reduction in ACL injury rates in females after neuromuscular training aiming to increase frontal plane knee control and thus reducing dynamic knee valgus (Hewett et al., 1999; Myklebust et al., 2003; Olsen et al., 2005; Soligard et al., 2008; Waldén et al., 2012). These findings further support the hypothesis that knee valgus is a key component of the ACL injury mechanism. As a consequence, peak knee valgus angles are considered to be an important factor when attempting to identify athletes at increased risk of ACL injury.

Given the gender differences in ACL injury rates, numerous studies have investigated potential differences in landing mechanics during athletic tasks between males and females. Compared to males, females seem to perform athletic maneuvers with decreased hip and knee flexion, and increased knee valgus and abduction moments (Malinzak et al., 2001; Lephart et al., 2002; Ford et al., 2003; Salci et al., 2004; Pollard et al., 2004; McLean et al., 2005c; Sigward & Powers, 2006; Pollard et al., 2007; Pappas et al., 2007; Carson & Ford, 2011). Gender differences also exists in proximal control of the knee joint during similar tasks, with females displaying greater lateral trunk displacement and range of trunk motion, altered trunk and hip flexion angles, and increased adduction and internal rotation of the hip compared to males (Mendiguchia et al., 2011). Furthermore, the gender differences seem to increase during maturation. Female athletes have demonstrated greater measures of knee valgus and abduction moments, with concurrent decreased neuromuscular control of the knee during puberty (Hewett et al., 2004; Schmitz et al., 2009; Ford et al., 2010).

While it is generally accepted that female athletes demonstrate movement patterns different from males, the underlying causes for these differences are not completely understood. It is likely that anatomical and neuromuscular characteristics may influence knee joint biomechanics, but the documentation of these potential relationships is rather limited, as it is based upon either of the factors alone and with conflicting results reported (Claiborne et al., 2006; Willson et al., 2006; Jacobs et al., 2007; Lawrence et al., 2008; Wallace et al., 2008; Hollman et al., 2009; Shultz & Schmitz, 2009; Bandholm et al., 2011; Nguyen et al., 2011; Cashman, 2012). A better understanding of how anatomical and neuromuscular characteristics collectively influence frontal plane knee kinematics may help clinicians improve training protocols to prevent non-optimal movement patterns and reduce injury risk. We therefore aimed to investigate the combined relationship between anatomical and neuromuscular characteristics and peak knee valgus angles in a vertical drop jump landing in Paper IV.

Risk factor screening

The aim of athlete screening is to assess and detect characteristics that potentially increase the risk of injury. If we can identify specific attributes, abnormalities or asymmetries that increase the risk of a subsequent injury, it may be possible to develop injury prevention programs tailored to the athletes at risk. Prevention of injuries could therefore be accomplished with greater success, and athletes can continue with their sport without the abruption, pain and costs that are associated with injuries.

Figure 4. Observational screening of frontal plane knee control during squatting.

During recent decades, several screening tools have been developed to assess potentially high-risk movement patterns in athletes, of which most are based on the suggested link between lower extremity kinematics and kinetics and ACL injury (Hewett et al., 2005). The majority of these tools have assessed knee valgus during a vertical drop jump task (Ford et al., 2003; Hewett et al., 2006; Ekegren et al., 2009; Padua et al., 2009; Myer et al., 2011; Stensrud et al., 2011; Mizner et al., 2012) or single-leg tasks, such as sidestep cutting maneuvers (McLean et al., 1999; McLean et al., 2004; Chaudhari et al., 2005; McLean et al., 2005a; Cowley et al., 2006; Sigward & Powers, 2007; Nagano et al., 2009; O'Connor et al., 2009).

Although laboratory based 3D motion analysis is considered “the gold standard” for assessing joint kinematics and kinetics of the lower extremities, it is widely acknowledged that this method is not suitable for large-scale screening of athletes due to its high costs and time-consuming nature. The ideal screening tool would have the ability to identify all players being at high risk, i.e. high sensitivity of the test, and provide reliable results. At the same time, it should be simple and easy to implement, require minimal equipment and be completed in a timely manner.

As a consequence, several reserarchers have attempted to develop simpler methods to screen for high-risk knee valgus angles (Figure 4). It is believed that the knee valgus observed in the frontal plane, often denoted as the frontal plane projection angle (FPPA), is representative of the dynamic knee valgus that can be measured using 3D techniques (McLean et al., 2005b). Thus, the correlation between two-dimensional (2D) and 3D kinematics during vertical drop jumps has been investigated in several studies. Ekegren et al. (2009) validated a set of novel observational screening guidelines to evaluate dynamic knee valgus in a drop jump landing by comparing screening scores to 3D motion analysis. The sensitivity and specificity for the screening test to identify high-risk individuals, defined as valgus angles above 10.83°, was moderate, ranging from 60% to 87%. Rater agreement was good, with Kappa coefficients for intra-rater and inter-rater agreement ranging from 0.75 to 0.85. Mizner et al. (2012) compared kinematics from 2D video recordings with 3D analyses, and reported that knee separation distance accounted for a higher variance of 3D knee valgus angles and abduction moments than FPPA. These authors reported intraclass correlation coefficients (ICC) of 0.89 to 0.97 for intra- and inter-rater agreement.

In an attempt to merge the gap between laboratory measures and clinical practice, Padua et al. (2009) developed a clinical assessment tool to identify potentially high-risk movement patterns in a jump-landing task. This Landing Error Scoring System (LESS) consists of 17 items assessing lower extremity and trunk positioning from frontal and sagittal views, and provides a total score for each athlete. The items are scored by trained reviewers, and a high LESS score indicates poor technique in a drop jump landing, whereas a lower score indicates better technique. The LESS was validated against 3D lower extremity kinematics and kinetics, and poor LESS-scores were associated with increased measures of valgus and abduction moments, increased internal hip and knee motion, and decreased hip and knee flexion angles.

Myer and colleagues developed a clinic-based prediction algorithm to identify athletes with high knee abduction moments and have published a series of four papers (Myer et al., 2010a; 2010b; 2010c; 2011). The clinic-based surrogate variables include measures of knee valgus motion and knee flexion range of motion during the landing of a vertical drop jump, body mass, tibia length and quadriceps-to-hamstrings strength ratio. This algorithm was validated against 3D measurements of knee abduction moments, demonstrating moderate to high agreement between methods (ICCs 0.66 to 0.99), suggesting that clinical measures can be used for large-scale screenings.

Although previous screening tools based on 2D measurements or clinic-based algorithms have shown promising findings with regards to identifying injury risk, real-time observational screening represents an easy and low-cost method for assessing knee valgus in a drop jump task. Furthermore, it could provide immediate feedback to the athlete and the coach. Stensrud et al. (2011) used a real-time observational screening tool to assess the ability of a physiotherapist to identify knee control and potential injury risk in female athletes. During a vertical drop jump task, single-leg squats and single-leg drop jumps, a physiotherapist scored their frontal plane knee control as being good, reduced or poor. These scores were compared to FPPA from video analyses, and athletes rated with poor control displayed significantly higher values of FPPA during the vertical drop jump and single-leg squats compared to players rated with good control. However, although the authors reported high intra-rater reliability, inter-rater agreement was not investigated. Reliable assessment criteria are necessary to standardize ratings and to ensure adequate reliability, and the ideal screening tool would demonstrate high inter-rater agreement. As such, the screening tool could provide similar findings when being applied by other clinicians, which is of importance for large-scale screenings. These issues were therefore addressed in Paper III, where we aimed to assess whether real-time observational screening would correlate to 3D knee kinematics and kinetics, and to further investigate inter-rater reliability of the screening tool.

To date, documentation is still needed with regards to risk factors for lower extremity injury in female football players and the screening tools necessary to identify injury risk. Given the association between knee valgus and injury risk, there is a need for development of reliable screening tools to assess knee valgus during sports specific tasks, as well as to investigate the predictive ability with regards to injuries. Moreover, assessing potential determinants for knee valgus during dynamic tasks could help providing a more complete understanding of the valgus observed in female athletes.

Aims of the thesis

The overall aim of the PhD project was to investigate risk factors for non-contact ACL injuries in elite female football players. The aims of this thesis were to investigate injury registration methods and injury risk in elite female football players, and to further assess how frontal plane knee kinematics in a drop jump landing can be identified. The specific aims of the separate papers were as follows:

1. To describe the injury pattern in Norwegian elite female football through individual player registration using text messaging, and to compare this novel method to routine team medical staff registration (Paper I)
2. To investigate intrinsic risk factors for lower extremity injuries in elite female football players (Paper II)
3. To assess whether physioterapists can identify female football players with high knee valgus angles in a drop jump landing using real-time observational screening, and to investigate inter-rater agreement between three independent physiotherapists (Paper III)
4. To investigate the relationship between anatomical and neuromuscular characteristics combined and peak knee valgus angles in a vertical drop jump landing (Paper IV)

Methods

The thesis is based on data collected from preseason screening of elite female football players from 2009 through 2012 at the Oslo Sports Trauma Research Center (OSTRC), as well as an individual prospective injury registration throughout the 2009 competitive football season. **Paper I** is based on the injury registration in 2009 and validates a novel method for injury registration in sports using text messaging by comparing it to routine registration by the team medical staff. **Paper II** describes intrinsic risk factors for lower extremity injuries, using the 2009 preseason screening tests and the subsequent prospective individual injury registration. **Paper III and IV** are based on data from the screening tests included in the cohort study to assess knee valgus angles during drop jump landings and measures of anatomical and neuromuscular characteristics.

Study design and participants

The main study from which all papers originate, is designed as a prospective cohort with the aim of investigating biomechanical, anatomical, neuromuscular and genetic risk factors for non-contact ACL injuries in elite female handball and football players. The first two years of data collection (2007-2008) included handball players from the Norwegian elite league (Postenligaen) only. Football players were included from 2009, and we invited all 12 teams in the Norwegian female elite league (Toppserien). An invitation letter was sent to the coach of each team with information about the project and practical details related to project participation. All players who were expected to play in the elite league during the following season were eligible for participation. Players with injury that kept them from full participation in team training and competition were excluded.

After the first year of screening, we invited all new players in the elite league during the subsequent seasons. Throughout the course of the study from 2009-13, a total of 405 elite female football players have been enrolled in the cohort.

Data collection

Data were collected annually during preseason (February-March) at the Norwegian School of Sport Sciences using a comprehensive set of screening tests. After scheduling the test days, we arranged all logistic details and covered the travel expenses and accomodation when needed for each player. All players spent about 7 h to complete all screening tests during one day of testing, including warm-up and a lunch break. After the baseline screening tests, all non-contact ACL injuries occurring during football training or match have been recorded. A priori power estimations indicated that 30-50 cases were needed to detect moderate to strong associations between the potential risk factors and new ACL injuries (Bahr & Holme, 2003). New players will therefore be included annually until we have recorded a sufficient number of injuries.

The screening tests

The baseline screening test battery included tests assessing biomechanical, anatomical and neuromuscular factors that potentially could predict future ACL injuries (Figure 5). In random pairs, players completed all tests located at seven different test stations in a pre-defined order.

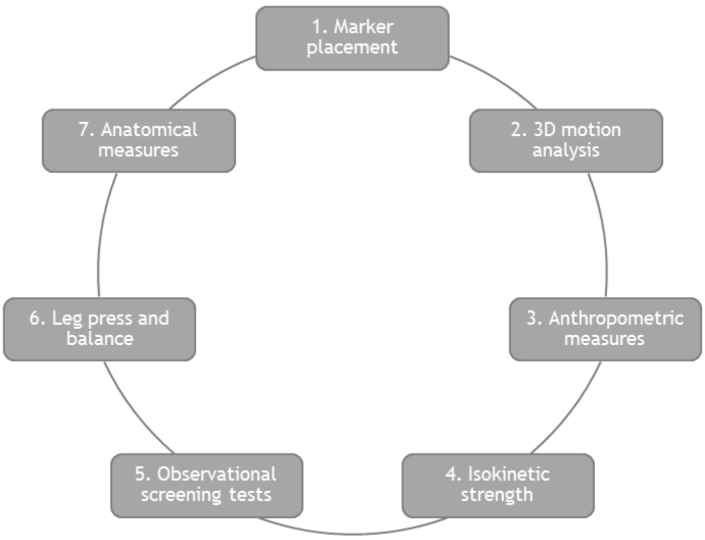

Figure 5. The baseline screening test battery including measurements located at seven different test stations.

Biomechanical screening tests

Kinematics and kinetics of a vertical drop jump

We assessed frontal plane knee kinematics (Paper II-IV) and kinetics (Paper III) during a vertical drop jump landing using marker-based 3D motion analysis (Figure 6). This method is considered the gold standard for assessing knee joint kinematics in a drop jump landing, with good to excellent reliability reported (ICC 0.62-0.99) (Ford et al., 2007). We used an optical tracking system with eight 240 Hz infrared cameras (ProReflex, Qualisys, Gothenburg, Sweden) for motion capture. The players wore shorts, a sports bra and indoor football shoes, and we attached 35 reflective markers to the torso and lower extremities over anatomical landmarks. One research assistant palpated the anatomical landmarks and placed the markers on all players to ensure standardization. To estimate inertia parameters, we obtained anthropometric measures of all players, including 46 measures of segment circumferences, heights and widths (Zatsiorsky & Seluyanov, 1983; Yeadon, 1990).

Figure 6. 3D motion analysis of a vertical drop jump task.

Starting on the top of a 30 cm high box with their feet shoulder-width apart, the players were instructed to drop off the box with a two-feet symmetrical landing, immediately followed by a maximal vertical jump. They were allowed up to three practice trials and at least three valid trials were collected for each player. The trial was valid when the markers stayed firmly on the skin and were visible for the cameras throughout the jump.

Marker trajectories were tracked with the Qualisys Track Manager (Qualisys, Gothenburg, Sweden), and these were filtered and interpolated with a 15 Hz cubic smoothing spline (Woltring, 1986). We determined the anatomical coordinate systems of the thigh and shank from a static calibration trial. The vertical axis was defined in the direction from distal to proximal joint center, the antero-posterior axis was defined perpendicular to the vertical axis, and the third axis was the cross product of the vertical and antero-posterior axis. Intersegmental moments were therefore expressed as flexion-extension, varus-valgus and internal-external rotation moments with respect to the cardanic axes of the knee joint coordinate system (Grood & Suntay, 1983). The contact phase was defined as the period where the unfiltered vertical ground reaction force exceeded 20 N. Peak knee valgus angles and abduction moments during the contact phase were calculated in custom Matlab scripts (Mathworks Inc., Natick, MA, USA), and external knee joint moments were calculated using inverse dynamic equations (Davis et al., 1991). Their zero posture was defined from the static calibration trial. This static trial was also used to extract player height and the length of the femur and tibia, and their body mass was recorded from two adjacently placed 960 Hz force platforms (AMTI LG6-4-1, Watertown, Massachusetts, USA).

From the 3D motion analysis we chose peak knee valgus angles and peak external knee abduction moments during the contact phase of the vertical drop jump as the main outcome variables. To define peak knee valgus angles in Paper II and IV, we averaged peak valgus across three trials for each leg separately. In Paper III, we calculated the average peak knee valgus angles for the right and left knee and chose the jump with highest measures of valgus out of three trials. The rationale for choosing the jump with highest valgus angles in Paper III was that we assessed two similar drop jump tasks, of which both evaluated the "worst" trial for the player that could potentially lead to an injury in a real-life situation.

Neuromuscular screening tests

For the Papers II-IV, we included neuromuscular tests assessing frontal plane knee control, dynamic balance and maximal lower extremity muscle strength. In Paper II, we wanted to investigate whether these tests could predict lower extremity injuries. In Paper III, we assessed the relationship between real-time observational screening of knee control and the vertical drop jump test assessed in the motion lab, and in Paper IV, we investigated the potential relationship between muscle strength and peak knee valgus angles during a drop jump landing.

Observational screening of frontal plane knee control

To assess frontal plane knee control during a vertical drop jump landing, the players performed a drop jump from a 30 cm high box (Figure 7). The players wore shorts, a sports bra and indoor football shoes, and prior to the jump we marked the anterior superior iliac spines and the tibial tuberosities with small pieces of sports tape. First, players performed a standardized warm-up procedure consisting of squats (2 x 8 rep) and maximal vertical jumps (2 x 5 rep), followed by calf-muscle stretching for 2-3 min. The players started on top of the box with their feet shoulder width apart and we instructed them to drop off the box, landing symmetrically on both feet and immediately perform a maximal vertical jump. To ensure maximal effort during the jump, we attached a football to a string hanging 260 cm above the floor, and the players were encouraged to try reaching it. A trial was judged invalid if the players jumped off the box or failed to perform a vertical jump after the first landing. The players were allowed up to three practice trials before completing three valid trials, of which the trial scored with poorest knee control was collected for analysis.

A sports physiotherapist assessed knee control in the frontal plane in the landing of the jump, using a graded scoring scale from 0 to 2. A score of 0 corresponded to "good control", where the participant displayed proper knee alignment, with a straight line from the knees to the mid-toes, no obvious valgus motion of either of the knees, and no medio-lateral side-to-side movements of the knee during the performance. The score of 1 corresponded to "reduced control" and indicated improper alignment, with one or both knees moving into a slight valgus position and/or some medio-lateral side-to-side movements during the performance. A score of 2 corresponded to "poor control" and was given when the alignment of the knees was poor, with at least one of the knees clearly moving into a substantial amount of valgus (i.e. knee medial to foot), and/or clear medio-lateral side-to-side movements of the knee.

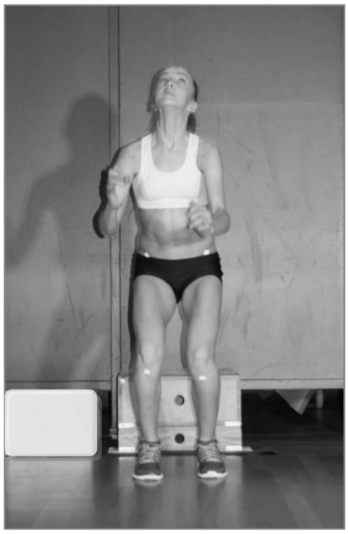

Figure 7. Assessment of frontal plane knee control in a vertical drop jump task.

From the screening tests conducted in 2009, three physiotherapists simultaneously and independently scored a total of 70 players. We used these data to compare the clinical test scores to objectively measured peak knee valgus angles and abduction moments from the 3D motion analysis, and further assess the agreement between the three raters (Paper III).

In addition to the vertical drop jump task, the players also performed single-leg squats and single-leg drop jumps from 10 cm height during which their frontal plane knee control was evaluated. Data from these tests have not been included in any of the papers of this thesis.

Isokinetic quadriceps and hamstrings strength

Maximal isokinetic quadriceps and hamstrings strength was tested in a Technogym REV 9000 dynamometer (Gambettola, Italy) (Figure 8). The test range of motion was 90° through 15° of knee flexion, with an angular velocity of 60°/s. Players had a 5-min warm-up with moderate load on a cycle ergometer, before the dynamometer was individually adjusted and the pelvis and upper body were fixed with two belts. We used a standardized test protocol and recorded the peak torque (Nm) for concentric quadriceps and hamstrings strength on both legs. Isokinetic muscle strength testing is a method widely used in clinical practice and has been established as a reliable tool for assessing muscle force, with ICCs of 0.81-0.97 (Brosky et al., 1999).

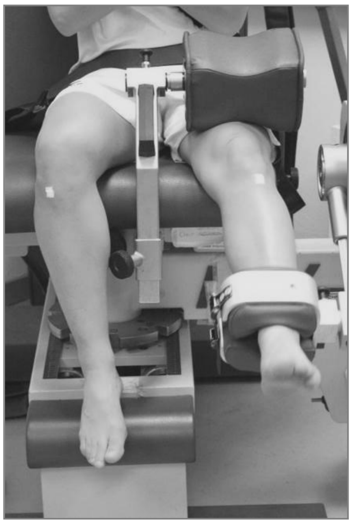

Figure 8. Isokinetic strength assessment of the quadriceps and hamstrings.

Isometric hip abductor strength

With the player supine on an examination table (Figure 9), we measured maximal hip abductor strength with a handheld dynamometer (Hydraulic Push-Pull Dynamometer, Baseline® Evaluation instruments, White Plains, NY, USA). The pelvis was fixed and the players held their arms across the chest to avoid hand support. We placed the dynamometer 2 cm proximally to the lateral malleolus and applied resistance in a fixed position for 3-5 s until a maximal isometric contraction had been reached. The players were allowed two trials and we recorded their best trial (kg). Similar procedures have been established as reliable for assessing hip abductor strength in athletes (ICC 0.84-0.97) (Thorborg et al., 2010; 2013).

Figure 9. Isometric hip abductor strength measured with a dynamomenter.

One repetition maximum (1 RM) in a leg press test

To assess hip and knee extensor strength, we used a seated custom-made leg press machine (Figure 10). The inter-rater reliability was found good (ICC 0.83) in an investigation from the same cohort (2013, unpublished data). The feet were placed shoulder-width apart on a footplate used to lower the weights to 100° of knee flexion before pushing back to the starting position. To ensure correct range of motion, a bar was placed at the point where the knees reached a flexion angle of 100°, measured with a goniometer. Based on a standardized protocol with gradually increasing load, we recorded their maxim (1 RM, kg).

Figure 10. The 1 RM leg press test.

Star Excursion Balance Test

To assess dynamic balance of the lower extremities, we used the Star Excursion Balance Test (SEBT), which has been found as a reliable measure for balance and ankle stability deficits (ICC 0.67-0. 87) (Kinzey & Armstrong, 1998; Plisky et al., 2006). From a center starting line, we attached three tape measures to the floor in anterolateral, mediolateral and posterolateral directions (Figure 11). The mediolateral direction was perpendicular to the starting line, and relative to this line, the antero- and posterolateral directions were at a 45° angle. The players performed the test without shoes, starting with balancing on the preferred kicking leg. While maintaining single-leg stance, we instructed the players to reach as far as possible with the contralateral leg in all directions and marked their maximal distances (cm). The trial was judged invalid if they failed to maintain balance on the stance leg; if they touched the floor with the contralateral leg; or if they were unable to move their leg back to the starting position. Their best out of three trials in all directions were recorded.

Figure 11. Star Excursion Balance Test.

Anatomical screening tests

For papers II and IV, we included tests assessing various anatomic characteristics to investigate their potential associations with lower extremity injuries (Paper II) and peak knee valgus angles in a drop jump landing (Paper IV).

Knee joint laxity

We measured anterior-posterior knee joint laxity using a KT-1000 arthrometer (MEDmetric Corp, San Diego, California, USA) with the players in supine on an examination table (Figure 12). With the knees flexed to 25 ± 5° over a thigh bolster, we applied posteriorly directed forces to the tibia to establish a zero reference point, followed by an anteriorly directed force of 134 N to measure anterior knee joint laxity (mm). We recorded their maximum out of two trials for both legs. The reliability of KT-1000 measurements by experienced raters has been shown to be good (ICC 0.79) (Berry et al., 1999).

Figure 12. Knee joint laxity measures.

Generalized joint laxity

To assess hypermobility, we used the 9-point Beighton scale (Beighton et al., 1973) (Figure 13). This scale is widely used for quantifying hypermobility, with good to very good reliability reported within and between raters (Spearmans rho: 0.81-0.86 and 0.75-0.87, respectively) (Boyle et al., 2003). Players were assessed for excessive joint laxity at the trunk, and bilaterally at the fifth finger, thumb, elbow and knee. Each joint received a score of 1 for each criteria met, giving a potential maximal score of 9. The threshold for hypermobility was defined as a score at or above 4, which indicated generalized joint laxity.

Figure 13. Generalized joint laxity assessment.

Foot pronation

We included the navicular drop test to assess foot pronation (Figure 14), and defined navicular drop as the difference in navicular height (mm) from standing with the subtalar joint in neutral position to the standing relaxed foot position. The players were barefoot, standing with their feet shoulder-width apart on a hard and elevated ground, and we marked the most prominent aspect of the navicular bone. The distance from the navicular bone to the floor in neutral and relaxed position was measured with a ruler, and we used procedures similar to those described by Shultz et al. (2006a), in which intra-rater and inter-rater reliability were reported as moderate to very good (ICC 0.91-0.97 and 0.56-0.76, respectively) (Shultz et al., 2006b).

Figure 14. The navicular drop test.

Questionnaire

Concurrent with the screening tests we collected information on personal data, such as age, team affiliation, playing position, average training volume (including football, strength and endurance), years of elite level experience and their dominant leg (preferred kicking leg) in a questionnaire. We also asked for previous injuries to the knee, ankle, hamstrings muscles and groin within the previous year, as well as any previous ACL injuries. In addition, included in the questionnaire were a Norwegian version of the Knee Injury and Osteoarthritis Outcome Score (KOOS) to assess knee function (Roos & Lohmander, 2003), and a form based on The Standardized Nordic Questionnaire on Low Back Pain (Bahr et al., 2004) to assess the prevalence and severity of low back pain among the players. Data from the questionnaires have been included in Paper II and IV.

The test team

To complete all these screening tests for each player within one day of testing, we needed a total of 15 research assistants designated to the different test stations each day. We recruited these assistants from the Norwegian School of Sport Sciences, and they were sports physiotherapists, medical students or MSc/BSc students in sport science. All members of the test team were thoroughly informed and trained to become familiar with our test procedures. As part of their training, we arranged at least two days of pilot testing where we invited local youth athletes to participate in our screening tests.

Throughout the years of screening from 2009 through 2013, several of the assistants in the test team have participated during all test periods and we have aimed for consistency. To ensure high reliability, we have developed standardized test procedures and all research assistants have received the same information and training.

Injury registration

Throughout the 2009 competitive football season, we invited all players in the elite female football league to participate in a prospective registration of exposure in training and match, as well as time-loss injuries occurring during football activity. We used these data for describing injury patterns in female football and validation of the new registration method in Paper I, and for the investigation of risk factors for lower extremity injuries in Paper II.

Injury definition and injury form

In accordance with the consensus statement on injury registration in football (Fuller et al., 2006) we used a time-loss injury definition. An injury was recorded if it resulted in a player being unable to take a full part in future football training or match play at least one day beyond the occurrence of injury. The injury was defined as acute if it was a result of a sudden, identifiable event and as an overuse injury if the onset was gradual and not related to one specific event. Injuries were recorded using an injury form collecting information on the injury circumstances, such as type of activity (match or training), the playing surface (natural grass or artificial turf), the injured body part, type of injury and the specific diagnosis. The injury severity was defined according to the number of days of absence from training and/or match as minimal (1-3 days), mild (4-7 days), moderate (8-28 days) or severe (>28 days). We defined players as being injured until they could participate fully in regular football training and match play with their team.

Individual registration of injuries and exposure

All players individually reported exposure and injuries throughout the season using text messaging (SMS), which was a new method based on an SMS-tracking system (New Agenda Solutions Aps, Copenhagen, Denmark). The registrations were conducted on a weekly basis through the automatic generation of three text messages sent every Sunday evening. One SMS was sent out for each of the three questions and the players replied to each of these:

1) How many minutes of match play did you do the last week? Sum up all matches and report the total number of minutes played.

2) How many hours of training did you do the last week? Sum up your total hours of football practice, rounding up to nearest full hour.

3) Have you had any injury or illness that has restricted you from full participation in one or more training sessions and/or matches the last week? Answer yes or no.

All responses were recorded in a system-generated database. If the players forgot to reply to one or more of the text messages, they automatically received a first reminder after two days and a second reminder after another two days. For each injury reported, we contacted the player by telephone to complete an injury form and collect information regarding the injury circumstances. We continued to follow up each injured player until she answered "no" on the question related to injuries, and she was then contacted to establish the correct number of days of absence. Injuries occurring before the start of the injury registration, or those occurring in activities other than football training or match were not included. The principal investigator (AN) conducted all telephone interviews, and these were completed within 1 to 4 days after an injury was reported.

In addition to the individual SMS-registrations, a member of the team medical staff from all 12 teams in the elite league concurrently recorded training and match exposure and injuries for their team. They completed a detailed exposure form designed as a calendar for each month, and used the same injury form as for the individual registration to record injuries. These forms were completed and returned once a month throughout the season.

Statistics

Data were analysed using SPSS for Windows, version 18 (SPSS Inc., Chicago, IL, USA), and descriptive data are presented as means ± standard deviations (SD) for Papers I-IV.

In **Paper I**, data were included for those players who completed at least the first five months of the registration period (n=205), and for team medical staff members who provided complete registration data (n=9). The analyses were therefore based on the 9 teams, including 159 players. Exposure data were calculated as the total hours of training and match play during the season, and injury rates were reported as the number of injuries per 1000 player hours with 95% confidence intervals (CI). We compared the rate ratio (RR) between the two methods using a z-test with 95% CI based on a Poisson regression model. The RRs were presented with the medical staff registration as the reference group. Accuracy and completeness was compared between the individual and medical staff registration, and Kappa statistics were used for assessing agreement between the two methods. Coefficients of 0.81 to 1.00 are generally interpreted as very good, 0.61 to 0.80 as good, 0.41 to 0.60 as moderate, 0.21 to 0.40 as fair, and less than 0.20 as poor (Altman, 1991).

Paper II was based on the individual injury registration from Paper I, and exposure and injuries were reported similarily. In total, 184 players completed all screening tests and 205 completed the injury registration, leaving 173 players who provided complete data from both and thus were included in the study. Their preferred kicking leg was regarded as their dominant leg, and strength measures were adjusted for body mass and presented as relative values. For the SEBT, the players' maximal reaching distance in all three directions was adjusted for leg length (calculated from the 3D motion analyses), and we calculated the mean relative score for the three directions for further analyses. From the 3D motion analyses we calculated the average peak valgus angles across three trials for both the right and left knee and analysed the legs separately. Demographic data and screening test scores were compared between players with and without any new lower extremity injury during the study period using Student`s t-test for continuous variables and chi-square tests for categorical data. To further investigate the risk factors for injuries, we used any lower extremity injury as the main outcome variable, and separate analyses were performed for injuries to the thigh, knee, ankle and lower leg/foot. For the dependent variable risk factor analyses, we followed a three-step model with similar procedures for all outcome variables. First, with each leg as the unit of analysis, we used generalized estimating equations (STATA, version 12.0; StataCorp, College station, Texas, USA) to calculate odds ratios

(OR) per one SD unit of change with 95% CI for all potential player-related risk factors for the outcome variables. For candidate risk factors with a p-value of <0.05, these findings were verified using binary logistic regression, allowing for repeated measurements across legs using robust estimation of standard errors. Following the univariate analyses, all factors with a p-value of <0.20 were investigated further in a multivariate model. To account for a potential over-optimism in the multivariate model estimates, we used the bootstrap method to estimate regression coefficients.

In **Paper III**, all three raters provided separate classifications of the 60 players included in the study. We set a consensus for their scores, defined as the score being given by at least two out of three, and consensus was reached for all 60 cases. Using the consensus scores, we investigated differences in knee valgus angles and abduction moments between the groups rated as having good, reduced and poor knee control using one-way ANOVAs. Post-hoc testing consisted of Tukey HSD. We used the Spearman`s rank correlation coefficient to assess the association between the classification of participants from the observational screening test scores (independent categorical variable) and knee valgus angles and abduction moments (dependent continuous variables). This analysis was performed for each of the raters, as well as for the rater consensus scores. As for Paper I, correlation coefficients of 0.81 to 1.00 were interpreted as being very good, 0.61 to 0.80 as good, 0.41 to 0.60 as moderate, 0.21 to 0.40 as fair, and less than 0.20 as poor (Altman, 1991).

To assess the ability of each rater to identify players with high knee valgus angles and abduction moments, we computed receiver operating characteristic (ROC) curves. The area under the curve (AUC) with 95% CI was presented for all three raters for both the kinematic and kinetic measures. Values range between 1.0 (perfect separation of the test values) and 0.5 (no apparent distributional difference), and is a quantitative expression of how close the ROC plot is to perfect (Zweig & Campbell, 1993). We further assessed inter-rater agreement between the three physiotherapists by calculating Kappa coefficients for paired assessments. The Kappa coefficient is based on the percentage agreement between raters and has been corrected for agreement expected by chance. Coefficients of 0.81 to 1.00 are considered as almost perfect agreement, of 0.61 to 0.80 as substantial agreement, of 0.41 to 0.60 as moderate agreement, of 0.21 to 0.40 as fair agreement, of 0.01 to 0.20 as slight agreement, while coefficients less than or equal to 0 are considered as poor agreement. As we did not find any differences in the classification between the raters, we set a consensus for their rating, defined as the score being given by at least two out of three raters.

In **Paper IV**, we included players providing complete data from the screening tests from 2009 through 2012, counting 279 in total. From the 3D motion analysis we included peak knee valgus angles during the contact phase of the vertical drop jump. Peak knee valgus angles were averaged across three trials for both the right and the left knee, providing separate peak values for each leg for all players. We used simple linear regression analyses to determine the individual relationships between all anatomical and neuromuscular factors (independent variables) and peak knee valgus angles (dependent variable) in a drop jump landing. Unstandardized regression coefficients were calculated separately for dominant and non-dominant legs.

Multiple linear regression analyses were used to investigate the amount of variance in peak knee valgus angles explained by anatomical and neuromuscular factors combined, with standardized regression coefficients reported. All legs were included in the regression model (n=558), clustered by player-ID to account for the relationship between left and right legs for each player. To further examine the relative importance of the independent factors in the multiple regression analysis, we calculated the effect of changing each of the anatomical and neuromuscular factors by 1 SD, keeping the others constant. This was done by multiplying the standardized regression coefficients with the SD of the corresponding factors, divided by mean valgus angles for all legs combined. One SD is considered a measure of the normal variation between subjects and shows the potential for variation and change in the intrinsic factors included in the current study.

For all four papers, the significance level was set at $p < 0.05$.

Ethics

The study was approved by the Regional Committee for Medical Research Ethics; South-Eastern Norway Regional Health Authority, and by the Norwegian Social Science Data Services, Norway. All players have signed a written informed consent to confirm participation in the project, including parental consent for players below 18 years of age.

Results and discussion

Text messaging for registration of injuries in football (Paper I)

During the 2009 football season, nine teams counting 159 players completed all registrations. Of these players, 121 (76%) sustained at least one injury, and a total of 232 unique time-loss injuries were recorded. Of these, 62% (n=144) were reported through player registrations only, 10% (n=23) by the medical staff only, and 28% (n=65) were captured by both methods. The majority of injuries were acute (68%), of which only 40% were recorded by the medical staff. We found a significantly higher incidence of match injuries from individual registrations compared to medical staff reports, with 18.6 (CI 14.7 to 22.5) versus 5.4 (CI 3.8 to 7.0), RR 3.4 (CI 2.4 to 4.9). This discrepancy was substantial across all nine teams, with the medical staff registration consistantly underestimating injuries.

Regardless of registration method, the knee was the body part most frequently injured; however, the medical staff registration captured only 41% of all knee injuries. Serious injuries causing absence of >4 weeks accounted for 27% of all injuries. The team medical staff registration captured only 50% of these, whereas the players reported all but one of the serious injuries (Figure 15).

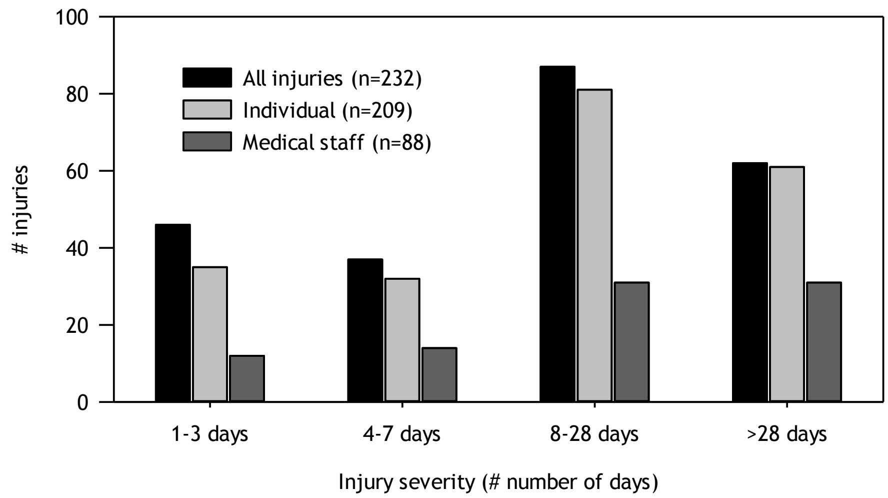

Figure 15. The severity of injuries (# days of absence) from individual registrations versus team medical staff registrations.

Out of the 65 injuries recorded by both methods, 53 had complete information on injury circumstances. The agreement between the methods was excellent for both injury location and injury type, with a Kappa correlation coefficient of 1.00, whereas the agreement was moderate for injury severity (0.48, CI 0.30 to 0.66).

Discrepancies between registration methods

Our findings documented that traditional medical staff registrations missed 2/3 of all injuries, whereas individual registrations using text messaging were more likely to provide a complete picture of the true injury burden in these football players. Furthermore, our results demonstrated that the underreporting by the medical staff was consistent across all injuries, regardless of injury type, location or severity. The surprising underestimation of injuries by the medical staff registration could be explained by their limited presence at training sessions during a regular week. Due to financial constraints in the female elite league, access to medical staff is a question of priority. On average, the team physiotherapists were present at one or two training sessions per week in addition to match attendance, which may have limited their possibility of capturing all injuries. However, if this were the case, we would expect it to affect the mild and minor injuries rather than those leading to several weeks of absence. Another reasonable explanation is the fact that they were aware of the concurrent individual registration by their players, which may have contributed to their low capture rate.

Similar findings have been reported among male professional football players. Bjørneboe et al. (2011) compared an injury surveillance system based on prospective medical staff registration to retrospective player interviews, and found that the medical staff underestimated injury incidence by one-fifth. Interestingly, in World Cup alpine skiing, only 47% of all injuries reported during one season were captured through prospective medical staff registration, whereas 91% were captured by retrospective player interviews at the end of the season (Flørenes et al., 2011). These findings suggest that medical staff recording is not always the best method for injury registration, and it seems clear that the injury incidence is dependent on how the injuries are recorded, by whom and when.

The challenges with variations in injury definitions and methodology have been addressed in previous reports (Inklaar, 1994; Finch, 1997; Junge & Dvorak, 2000; Fuller et al., 2006), and it is clear that "one size does not fit all" when it comes to injury surveillance methods (Clarsen & Bahr, 2014). Our results support individual registration of injuries and exposure rather than relying on others recording their injuries. Text messaging appeared to be a feasible and convenient tool for injury registrations as we could reach the players without the need for direct personal contact, which likely also explains our high response rate (90%).

Future injury registrations

Injury registration is a key risk management tool, and although injury patterns seem to be well documented and consistent across several years, injury surveillance is still essential for monitoring injury patterns and evaluation of prevention measures. Although text messaging was found valid and reliable for recording injuries, both in the current and recent studies (Møller et al., 2012; Ekegren et al., 2014), we acknowledge the challenge with recording overuse injuries using a time-loss definition. The characteristics and burden of overuse injuries are more difficult to capture reliably using the current injury definiton due to the gradual onset and fluctuating or transient symptoms of these injuries (Bahr, 2009). They may not lead to time loss from sports, but the athlete may continue to train and compete with presence of pain and reduced function. Based on these potential underestimations or misclassifications of overuse injuries, a new method for recording overuse injuries has been developed and validated at the Oslo Sports Trauma Research Center (Clarsen et al., 2013a). This new approach is based on weekly questionnaires with questions on symptoms related to pain, function and their effect on training volume and performance. Based on a severity score, they could quantify the magnitude of overuse problems, and this method has been found to capture 10 times as many cases as the traditional method. The same questionnaire was used for monitoring overuse problems in both individual and team elite athletes during the year preceding the London Olympic Games (Clarsen et al., 2013b). Currently, the prevalence of overuse problems such as pain, reduced function and performance has not been sufficiently documented in female football, and should be assessed using similar methods.

So, how should we record injuries in the future? To date, mobile platforms may bridge the gap between the researchers and the athletes, and the rise in use of smartphones and apps in recent years has offered a new and direct way to communicate research. Smart phones provide portability and availability, and various apps for promoting physical activitity, managing training diaries or providing injury prevention programs have emerged lately (van Mechelen et al., 2013). Further development of such tools has the potential to provide cost-effective, reliable and effective injury registrations in sports, and there is still a need for monitoring and describing injury patterns in youth and senior female football.

Risk factors for lower extremity injury (Paper II)

Our results are based on 173 players providing complete data from both the preseason screening tests and the prospective injury registration (age 21.5 ± 4 years, height 167 ± 5 cm, body weight 62 ± 6 kg). A total of 171 lower extremity injuries were reported in 107 of these players during the competitive season. We found that players suffering a lower extremity injury during the season had a greater BMI compared to players with no injuries (22.6 ± 1.7 versus 21.8 ± 1.7, OR: 1.55, CI 1.24 to 1.94) (Table 4). In the univariate analyses, greater foot pronation was also associated with new lower extremity injuries, giving a 23% higher injury risk per SD increase (CI 1.00 to 1.51). In the multivariate analyses, BMI was the only factor associated with increased lower extremity injury risk (Table 5).

Table 4. Risk factors for lower-extremity injuries using univariate regression analyses, comparing injured (n=107) versus non-injured (n=66) players

	Injured (n=107)	**Non-injured (n=66)**			
Player-related factors	Mean ± SD	Mean ± SD	OR	95% CI	p-value
Age (years)	22.1 ± 4.3	20.4 ± 3.7	1.21	[0.99-1.47]	0.06
Height (cm)	166.6 ± 5.0	167.2 ± 5.7	0.93	[0.75-1.15]	0.51
Body mass (kg)	62.8 ± 5.9	61.2 ± 6.3	1.34	[1.07-1.68]	0.01
Body mass index (kg/m^2)	22.6 ± 1.7	21.8 ± 1.7	1.55	[1.24-1.94]	≤0.001
Seasons at elite level (years)	3.6 ± 3.5	3.2 ± 3.3	1.00	[0.83-1.21]	0.96
Match and training exposure (h)	249.1 ± 69.9	275.4 ± 79.4	0.86	[0.64-1.15]	0.21

Results are presented as mean ± SD, with the risk for new injuries reported as OR per SD unit of change in player-related factors with 95% CI and p-values.

Knee injuries dominated and we recorded 53 injuries in 45 knees. The univariate analyses revealed that a previous ACL injury in the right knee gave a 9-fold increased risk of sustaining a new knee injury on the same side (OR: 9.08, CI 1.90 to 43.44). No such association was found for the left knee, and none of the candidate factors in the multivariate analyses were found to increase the risk of a new knee injury.

Table 5. Multivariate analyses including all risk factor candidates achieving P<0.20 in univariate analyses

Injury location	Intrinsic factors	OR	95% CI	p-value
Lower extremity				
	BMI	1.51	[1.21-1.90]	0.001
	Foot pronation	1.25	[0.99-1.59]	0.06
	Age	1.24	[1.00-1.54]	0.09
	Knee valgus angles	0.90	[0.71-1.15]	0.46
	Previous ACL injury	1.55	[0.42-5.68]	0.51
Thigh				
	BMI	1.51	[1.08-2.11]	0.01
	Hamstrings strength	1.45	[0.98-2.16]	0.06
	Previous hamstring injury	1.35	[0.42-4.38]	0.62
Knee				
	Previous ACL injury	3.30	[0.82-13.3]	0.09
	Knee valgus angles	0.12	[0.01-1.30]	0.18
	Foot pronation	1.28	[0.87-1.90]	0.26
	Previous ankle injury	1.46	[0.64-3.31]	0.37
	Knee laxity	1.12	[0.84-1.51]	0.47
Ankle				
	Knee valgus angles	0.64	[0.41-1.00]	0.04
	Foot pronation	1.55	[0.99-2.41]	0.07
	1 RM leg press	1.41	[0.97-2.06]	0.07
	Age	0.65	[0.40-1.05]	0.08
Leg/foot				
	Previous knee injury	3.57	[1.27-9.99]	0.02
	Age	1.47	[0.98-2.20]	0.06
	BMI	1.40	[0.90-2.17]	0.14

The ORs per SD unit of change in test scores (with 95% CI and p-values) result from generalized estimating equations including the bootstrap method

We also analysed thigh, ankle and leg/foot injuries separately. As for lower extremity injuries in general, greater BMI was found to increase the risk of thigh injury by 51% (CI 1.08 to 2.11) in the multivariate analyses, whereas neither muscle strength, nor anatomical characteristics were associated with new injuries. For ankle injuries, players displaying lower knee valgus angles in a drop jump landing were more likely to sustain a new injury (OR: 0.64, CI 0.41 to 1.00). Looking at leg and foot injuries, we identified a previous knee injury to give a more than 3-fold increased risk of sustaining an injury (OR: 3.57, CI 1.27 to 9.99).

Body composition and injury risk

BMI showed to be the strongest independent factor associated with new lower extremity injury, increasing the injury risk by 51% per one SD increase. Greater BMI was also associated with thigh injuries, but not to any of the other injury locations in our subgroup analyses. It could be hypothesized that greater body mass will produce greater forces, which are absorbed through soft tissue and joints, and thereby increases the stress on these structures and influence lower extremity injury risk. Moreover, more than half of the body mass is located in the upper body, and a link has already been established between trunk and upper body kinematics and lower extremity loading during sport specific tasks (Dempsey et al., 2007; Jamison et al., 2012). However, although these differences were statistically significant, we acknowledge that the difference in BMI between injured and non-injured players was relatively small (22.6 versus 21.8, respectively, corresponding to 1.6 kg for the average player). The clinical relevance of this finding is therefore likely limited.

As only three studies have investigated risk factors for injuries in senior female soccer players (Östenberg & Roos, 2000; Söderman et al., 2001b; Faude et al., 2006), of which only one included elite players (Faude et al., 2006), comparisons with findings from other studies are difficult. Furthermore, before drawing direct comparisons between their investigations and our, we should keep in mind the methodological differences between studies, such as injury definitions, inclusion criteria and statistical procedures. In contrast to these, we excluded all contusions, as these are caused by direct contact with another player and we believe that they are not explained by intrinsic factors. We also excluded injuries to the head, trunk and upper extremities, and we used the leg rather than the player as the unit of analysis.

Nevertheless, Faude et al. (2006) identified an increased injury risk for taller players and higher body mass in players sustaining non-contact injuries. In contrast, Östenberg & Roos (2000) found no association between height, body mass or BMI and new injuries, whereas Söderman et al. (2001b) did not assess this potential relationship in their investigation. Two investigations among youth female football players identified no association between body mass or BMI and injury risk (Emery et al., 2005; Steffen et al., 2008a). In contrast, one study among high school male and female athletes combined reported a relationship between overweight, as indicated by BMI, and increased risk for ankle sprains (Tyler et al., 2006). Furthermore, in a recent study among school children, greater BMI and greater percentage of body fat increased the risk of lower extremity injury during a 2.5 years follow-up (Jespersen et al., 2013).

Neuromuscular factors and injury risk

Interestingly, we identified lower knee valgus angles in a drop jump landing as being associated with increased injury risk. With one exception, our univariate analysis revealed a trend towards lower knee valgus angles in all players sustaining injuries, regardless of the injury location, although statistically significant for ankle injuries only. Players with lower peak knee valgus angles had a 36% higher risk of sustaining an ankle injury. This was somewhat surprising, considering that high knee valgus angles in a drop jump landing have been suggested to predict ACL injuries in a cohort of female athletes (Hewett et al., 2005). Moreover, lower extremity injury rates in females have been reduced after neuromuscular training specifically aiming to reducing dynamic knee valgus (Hewett et al., 1999; Olsen et al., 2005; Soligard et al., 2008).

A potential explanation for these findings may be that players displaying low knee valgus angles in drop jump landings, and thus proper frontal plane knee control, are better soccer players who are also more involved in game situations that entail a higher injury risk. However, in our multivariate analyses, knee effect of knee valgus on injury risk was only evident for ankle injuries. Moreover, we acknowledge that there are some potential sources of error throughout the steps of the 3D analysis, and the clinical relevance of a difference of 2.3° of valgus may be questionable.

Although muscle strength likely improves dynamic stability and thus may reduce lower extremity injury risk, we found no differences in lower extremity muscle strength between players with and without new injuries. Similar findings were reported by Östenberg & Roos (2000), where no association between isokinetic hamstrings or quadriceps strength and new injuries was found. In contrast, low concentric hamstrings-to-quadriceps strength ratio was associated with traumatic leg injuries in Swedish senior female players (Söderman et al., 2001b). Interestingly, although not significant we could see a tendency towards greater quadriceps and hamstrings strength in players sustaining thigh and ankle injuries, whereas players suffering from a knee injury demonstrated slightly lower measures of muscle strength. In contrast, greater eccentric hamstrings strength has been shown to protect male professional football players from hamstring injury (Askling et al., 2003; Arnason et al., 2008; Petersen et al., 2011). One could speculate that these conflicting findings are related to the fact that we only measured concentric strength, whereas eccentric strength is of greater importance for reducing hamstrings strains.

Previous injury and injury risk

Univariate analyses revealed a nine-fold increased risk for knee injury in players with previous ACL injury in the same knee, although they underwent ACL reconstruction and managed to return to high-level sports. Interestingly, this finding was only evident for the right knee, whereas no such relationship was found for the left knee. This could be limited by sample size or the potential side-to-side differences in football players related to limb dominance and different demands during the game. A previous knee injury also gave a nearly four-fold increased risk of new lower leg/foot injuries, although we found no associations between previous injuries to the thigh, knee or ankle and new injuries to the same location. Nevertheless, these findings emphasize the importance of injury prevention efforts and sufficient rehabilitation time for injured players, and we assume that easy access to medical treatment likely influences the recurrence rates.

In accordance with our findings, an increased risk of new knee injuries was found in male football players with a previous ACL rupture (Waldén et al., 2006). Although one study (Faude et al., 2006) found an increased risk of new ACL injury in elite female football players with previous ACL injury, they found no associations between injury history and new injuries for other lower extremity injuries. In contrast, previous injuries have been reported as significant predictors for new injuries in youth female players (Emery et al., 2005; Steffen et al., 2008a) and among male football players (Arnason et al., 2004; Hägglund et al., 2006; Waldén et al., 2006; Engebretsen et al., 2010a; Engebretsen et al., 2010b; Engebretsen et al., 2010c; Hägglund et al., 2013).

Better players – higher risk?

Interestingly, a common finding across tests and outcomes were that players performing better on functional tests were more likely to sustain an injury, i.e. displaying lower knee valgus angles in a drop jump landing or scoring higher on a maximal lower extremity muscle strength tests. This corresponds to the findings by Östenberg & Roos (2000), who found that players achieving better scores on functional balance tests were more likely to sustain an injury. It may be speculated that highly fit players are at greater risk simply because they are more involved in the game, or that improved performance and better skills may lead to an increased risk taking behaviour on the pitch. This assumption is supported by a study among youth female players (Soligard et al., 2010b), where those classified with high technical and tactical skills, and greater muscle strength and agility were more prone to lower extremity injury than players with low skills. When looking more closely into our data we could also see that midfielders were more likely to sustain injuries, supporting the idea that players with more ball possession and game involvement in general are more prone to injury.

Observational screening of knee valgus in drop jumps (Paper III)

A total of 60 players provided complete data from the real-time observational screening test and the 3D motion analysis. Players rated with poor frontal plane knee control displayed greater knee valgus angles in a drop jump landing compared to players with good knee control ($p \leq 0.001$, Figure 16). The players rated with reduced knee control differed from both the group rated as good ($p=0.01$) and poor ($p=0.01$).

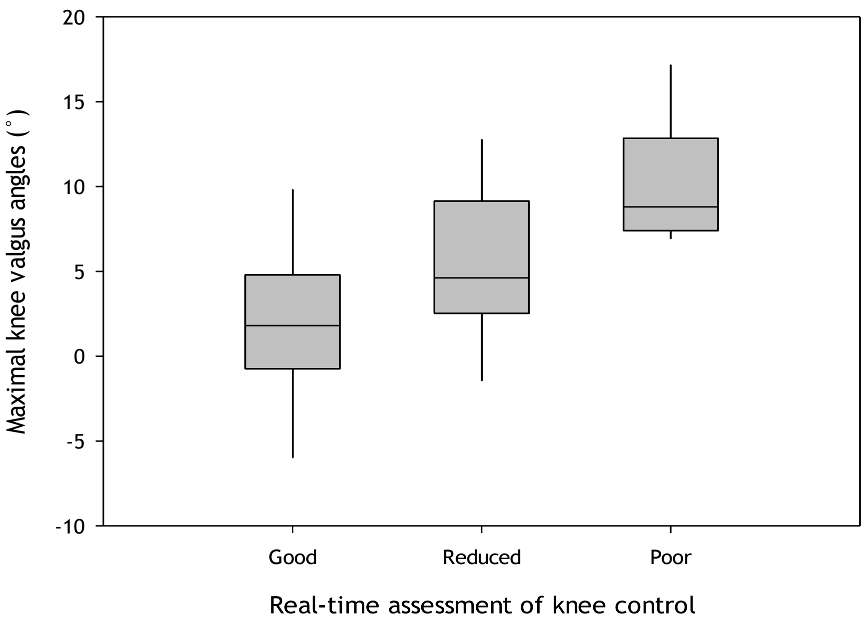

Figure 16. Differences in knee valgus angles between the groups of participants rated as having good (n=20), reduced (n=20) and poor knee control (n=9). The box represents the interquartile range with the median and range of knee valgus angles.

We found a moderate correlation between the real-time observational screening test scores and knee valgus angles for all three raters, with correlation coefficients ranging from 0.54 to 0.60, whereas we found no correlation for abduction moments (Table 6). These findings were confirmed in the Receiver Operating Characteristic Curve (ROC) analyses. All three raters could successfully identify players with high knee valgus angles, whereas we found poor discriminative accuracy of the screening test for peak knee abduction moments.

Table 6. Spearman`s rank correlation coefficients (95% CI) evaluating the association between observational screening test scores and knee valgus angles and abduction moments for all 3 raters and the rater consensus

	Valgus angles			Abduction moments		
	Correlation	95% CI	p-value	Correlation	95% CI	p-value
Rater #1	0.58	0.39 to 0.74	≤ 0.001	0.11	-0.16 to 0.35	0.40
Rater #2	0.54	0.34 to 0.70	≤ 0.001	0.11	-0.15 to 0.34	0.39
Rater #3	0.60	0.41 to 0.75	≤ 0.001	0.09	-0.17 to 0.32	0.49
Rater consensus	0.56	0.34 to 0.71	≤ 0.001	0.11	-0.16 to 0.34	0.41

Our findings also revealed substantial to almost perfect inter-rater agreement between the raters, with percentage agreement ranging from 70% to 95%, and Kappa coefficients from 0.52 to 0.92. Rater 2 and rater 3 achieved highest agreement for all ratings with a Kappa coefficient of 0.92.

Observational screening versus objective measures of knee kinematics and kinetics

This study was initiated based on two assumptions. First, high knee valgus angles and abduction moments have been identified in female athletes later sustaining ACL injuries (Hewett et al., 2005). Second, reduced rates of knee injuries have been reported after the use of injury prevention protocols targeting proper knee alignment during dynamic tasks (Myklebust et al., 2003; Soligard et al., 2008; Waldén et al., 2012). Furthermore, to enable efficient large-scale screenings of athletes to identify injury risk, we need simple and reliable assessment tools providing real-time feedback to the athletes and their coaches.

The findings of this study suggest that we can successfully identify players with high knee valgus angles in a drop jump landing using real-time observational screening, and that similar findings can be obtained by other raters assuming they are provided with similar rating instructions and training. Our observational classifications of knee control correlated moderately with objective measures of knee valgus, and we found a discriminating accuracy (AUC) of 0.85 to 0.89 for all 3 raters with regards to identifying high valgus angles and distinguishing players with poor control. All players who were rated with poor knee control from the screening test displayed knee valgus angles above the overall mean value. This was also the case for 75% of players being classified with reduced knee control, indicating that players who may benefit from injury prevention training were identified with our screening test.

These findings are in accordance with previous studies, in which subjectively assessed knee control was correlated to objective measures of knee valgus, either by using 2D (Stensrud et al., 2011) or 3D (Ekegren et al., 2009) measurement tools. Furthermore, Mizner et al. (2012) found high agreement between measures of knee separation distance and frontal plane projection angles from 2D and 3D recordings, suggesting that resource-demanding methods such as 3D analyses are not necessary for describing frontal plane knee kinematics.

However, although our observational screening test scores correlated to knee valgus, we found no correlation for knee abduction moments and a poor discriminative accuracy of the test. The screening test can therefore not be used to identify athletes with high knee abduction moments. Furthermore, we found a low correlation between valgus angles and abduction moments ($r=0.04$). This could be seen as somewhat surprising, considering that both high valgus angles and abduction moments were found in athletes who subsequently ruptured their ACL (Hewett et al., 2005). However, we should also consider the fact that the prospective study which identified high knee valgus angles and abduction moments as predictors for ACL injury only included nine injured athletes. Thus, until prospective studies with a substantially larger sample size can confirm these findings, there is still a lack of knowledge as to what extent valgus angles or abduction moments in a drop jump landing predict injury.

The vertical drop jump task

The screening test investigated in the current study is simple and easy to implement in clinical settings, and it requires no equipment but a box and one clinician rating the athletes. As it is based on real-time observational screening, it provides immediate feedback to the athlete and therefore represents an effective, low-cost test. Thus, it is suitable for large-scale athlete screenings to identify potentially high-risk movement patterns in athletes. Moreover, we found high inter-rater agreement between the physiotherapists, although their clinical experience ranged from 5 to 20 years. Rater consensus was reached for all 60 cases, i.e. at least two out of three raters provided the same score for each of these players. This further supports that the current screening test can be applied by other raters and that similar findings can be expected, assuming that similar training is provided.

However, given the fact that ACL injuries typically occur during unilateral loading in sidestep cuttings and single-leg landings (Boden et al., 2000; Olsen et al., 2004; Krosshaug et al., 2007; Boden et al., 2009; Hewett et al., 2009), screening tools assessing potential risk factors in activities imitating these injury situations may be more valid. We acknowledge that the vertical drop jump may not be sufficiently challenging for provoking high valgus loads in all athletes. Furthermore, this motion task is predominantly single-plane in nature and therefore of less complexity than e.g. a multi-planar cutting maneuver. Athletes displaying high knee valgus angles in drop jumps are likely to display even higher angles during sidestep cutting, and knee abduction moments can be close to five times higher in a sidestep cutting task compared to a vertical drop jump (Kristianslund & Krosshaug, 2013). On the other hand, observational screening of knee valgus during a side-step cutting maneuver would be a challenging task for the rater and is less likely to produce valid and reliable measures.

We acknowledge the potential limitation of the current study due to the fact that two separate jumps were evaluated. Although the instructions and procedures were similar, the players may have performed the two jumps differently. However, the drop jump task is familiar for most of these athletes, and we believe that this test captures their individual landing technique even though they performed the task in two different laboratories. Another limitation may be related to the fact that we chose to average the 3D measurements for the right and left knee rather than analysing the limbs separately. Thus, potential side-to-side differences may have been masked. However, as the screening test is based on an overall evaluation of frontal plane knee control taking both legs into account, we believe that using the mean values would provide a better comparison to the screening test. Finally, we included elite athletes only and do not know whether similar findings would be obtained among younger females during adolescent growth spurt, where changes in lower extremity biomechanics (Hewett et al., 2004; Schmitz et al., 2009; Ford et al., 2010) and high knee injury rates (Emery et al., 2005; Steffen et al., 2007; Le Gall et al., 2008; Soligard et al., 2010a) have been reported.

Anatomical and neuromuscular determinants for peak knee valgus (Paper IV)

This paper included 279 players providing complete data from all screening tests from 2009 through 2012. Using simple linear regression analyses, the strongest independent association between anatomical and neuromuscular characteristics and peak knee valgus angles was found for static knee valgus, with unstandardized regression coefficients of 0.56 and 0.48 for dominant and non-dominant legs, respectively. In the multiple regression model, anatomical and neuromuscular factors combined explained 13% of the observed variance in peak knee valgus angles ($p<0.001$). Player height, static knee valgus and hip abductor strength were the only significant factors, with static knee valgus being the strongest predictor of peak knee valgus angles ($\beta=0.27$) (Table 7).

Table 7. Anatomical and neuromuscular factors as predictors for peak knee valgus angles using multiple regression analyses.

Test variables	β coefficient [a]	SE [b]	P-value
Height	0.146	0.042	≤0.001*
Static knee valgus	0.267	0.079	≤0.001*
Knee laxity	-0.026	0.124	0.539
Foot pronation	-0.030	0.065	0.464
Quadriceps strength	-0.059	0.011	0.274
Hamstrings strength	-0.102	0.021	0.075
Hip abductor strength	-0.115	0.076	0.004*

[a] *Standardized coefficients.*
[b] *SE, standard error.*
* *Relationship is significant at the p<0.05 level.*

We further examined the relative importance of the independent factors by calculating the effect of increasing each factor by 1 SD keeping the others constant. An increase in static knee valgus by 3° or height by 6 cm was associated with an increase in peak knee valgus of 0.8°, whereas increasing hip abductor strength by 2.8 kg decreased knee valgus by 0.3° (Figure 17).

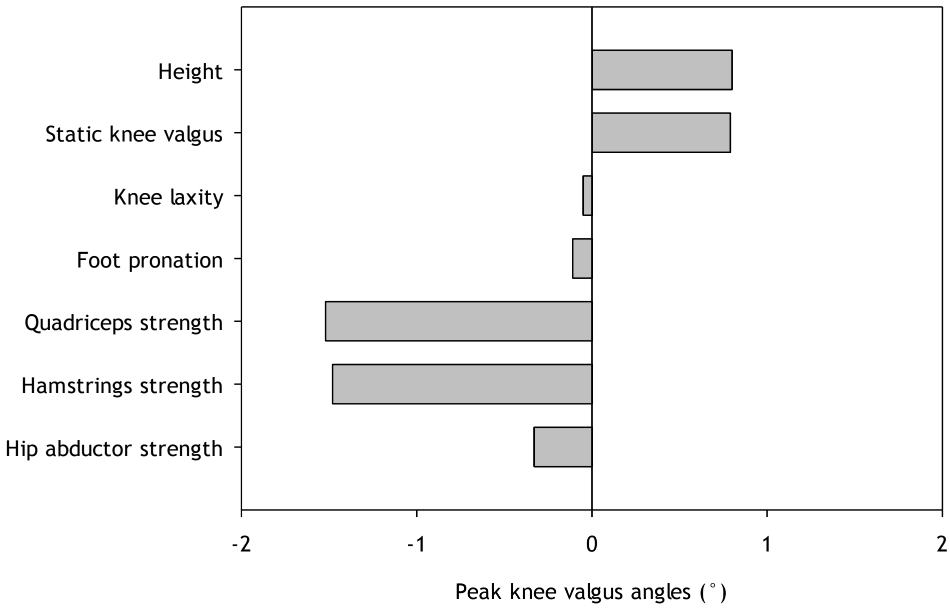

Figure 17. The effect on peak knee valgus angles (° change) by increasing each factor 1 SD, keeping the others constant.

Non-modifiable characteristics and knee valgus

Although non-modifiable anatomical characteristics can not be altered, increased awareness on how they influence knee valgus in dynamic tasks would improve our understanding of why some athletes are at greater injury risk. Two of the anatomical characteristics were identified as predictors for peak knee valgus; static knee valgus and player height, with static knee valgus being the strongest predictor among all variables. Taller players were also more likely to display greater valgus angles in the drop jump landing. From both a clinical and biomechanical perspective, this was not a surprising finding, considering that body height was highly correlated with tibia and femur length, and that longer lever arms likely produce greater forces pushing the knee into valgus. However, even though these two measures were significantly associated with peak knee valgus, the regression coefficients were low. Furthermore, the relative importance of these variables was limited, as an increase of 3° in static knee valgus or 6 cm in body height each corresponded to an increase in peak knee valgus of 0.8° only.

In accordance with our findings, Nguyen et al. (2011) found a correlation between lower extremity alignment and components of dynamic valgus during a single-leg squat, with greater valgus alignment, greater hip internal rotation and a smaller pelvic angle being predictive of dynamic valgus motion. In contrast, Pantano et al. (2005) identified no association between static and dynamic knee valgus. Both of these investigated a single-leg squat, whereas a vertical drop jump may reveal different motion patterns, suggesting that the potential relationship is dependent on the task being evaluated.

Modifiable characteristics and knee valgus

Determinants that are modifiable are of particular importance, as we can intervene on these factors and thereby potentially increase or decrease the variable of interest. The third most important predictor of our regression model was hip abductor strength. We identified greater peak knee valgus angles in players with reduced strength of the hip abductors. This finding suggests that a knee problem may have a proximal origin, and that hip abductors contribute to knee control during dynamic activities associated with sports. Clinically, this was not surprising, as decreased strength of the hip abductor may permit greater frontal plane knee excursion. However, the relative importance of hip abductor strength was rather low, as increasing strength by 2.8 kg would reduce peak knee valgus by 0.3° only. The clinical relevance is therefore likely limited.

The relationship between lower extremity muscle strength and knee kinematics is not completely understood, as there are inconsistencies in the literature with regards to how strength may affect knee valgus. In a systematic review (Cashman, 2012), only five out of 11 studies found a correlation between hip strength and knee valgus; of which four found evidence that participants with weaker hip muscles demonstrated greater valgus. In accordance with our findings, lower hip abductor strength has been correlated to greater knee valgus displacement in drop jumps (Jacobs et al., 2007; Wallace et al., 2008) and single-leg squats (Claiborne et al., 2006; Willson et al., 2006). In contrast, other investigators found no such a relationship, neither during single-leg landing tasks (Russell et al., 2006; Lawrence et al., 2008) nor a single-leg squat (Hollman et al., 2014). Surprisingly, one study (Hollman et al., 2009) reported opposite findings, with greater hip abductor strength being associated with greater knee valgus angles during a single-leg step-down task in active females. However, they included 20 participants only, and knee valgus angles were estimated from 2D video recordings. The large variability in findings reported from existing literature may be explained by discrepancies in study methodology, sample size and difficulty of the tasks evaluated. We included a large sample and our estimates are likely more robust than what has been reported from previous studies.

A better understanding of the underlying causes for an athlete to display high knee valgus during dynamic tasks is important and may help clinicians to develop tailored injury prevention programs. We identified static knee valgus, body height and hip abductor strength as the only factors significantly associated with peak knee valgus angles in a drop jump landing. Clinically, it seems reasonable that static knee valgus and greater body height, and thus longer lever arms of the lower extremities, in combination with reduced hip abductor strength would contribute to greater knee valgus angles. Nevertheless, our findings revealed that 87% of the variance in observed peak knee valgus angles remains to be explained by other factors than those included in our investigation. As a consequence, determinants for knee valgus angles and the combined contribution from various anatomical and neuromuscular characteristics needs to be further assessed, and both double- and single-leg tasks should be evaluated.

Methodological considerations

Risk factor assessment (Paper II)

As we know that a combination of several individual characteristics may predispose an athlete to injury, we included screening tests assessing various anatomical and neuromuscular characteristics. To date, our study (Paper II) is the first to include such a comprehensive set of screening tests to assess injury risk factors in female football players. Furthermore, the risk factor analyses were based on individual weekly injury registrations using text messaging, which was found to provide a complete picture of injury patterns in female football and was found superior to medical staff registrations in Paper I. We believe that this represents a major strength of the study.

In contrast to existing studies among females, we excluded all muscle and bone contusions, as they result from contact situations that are unlikely to be fully explained by anthropometric, anatomical or neuromuscular factors. Moreover, studies on injury risk have traditionally used the player as the unit of analysis. However, individual characteristics such as muscle strength, balance and stability, as well as lower extremity alignment, is likely related to the injured limb. We therefore used the leg as the unit of analysis, taking into account that two legs belonged to the same player. We also believe that our multivariate approach using the bootstrap method to account for potential overoptimism of the data strengthens the findings of the study.

Based on existing knowledge, we know that injuries are likely multifactorial in nature. There is not necessarily only one single factor leading to an injury, but rather a combination of factors that contributes to injury risk. Our findings are limited to the fact that we only assessed intrinsic factors, and thus have no information on the potential external risk factors that might have influenced injury risk in these players. For example, we do not know their exposure on artificial turf versus natural grass, exposure in other types of training or activities, the effect of shoe type on performance and injury risk, or the weather conditions at the time of injury.

We also acknowledge that our investigation did not take psychosocial factors into account. Life stressors, hassle, poor sleeping habits, overload or lack of motivation are factors that may influence an athlete`s behaviour and vulnerability to injuries (Steffen et al., 2009; Ivarsson & Johnson, 2010; Johnson & Ivarsson, 2011; Ivarsson et al., 2013a; Ivarsson et al., 2013b). Such potential mediators were not assessed, and we are therefore aware of the fact that the current study only covers one part of the spectrum when we aim to identify injury risk.

The screening tests (Paper II-IV)

The screening tests in our large cohort study were chosen based on findings from previous investigations and these tests have also been found reliable. Our screening test protocol has been identical throughout the years of testing; our instructions and training protocols have been the same, and we have put a large effort in keeping the test team as stable as possible. The test team has been stable within the same year, and we have aimed to keep the same assistants across test years. However, we cannot disregard the fact that there have been some changes within the test team, and with new research assistants participating, it could to some degree have affected our measurements.

Each player spent about 7 h to complete all screening tests, and they were present until all tests were completed. Some of these tests are challenging and exhausting, and players may be less motivated towards the end of the day. This may have affected their performance and the scores on some tests. On the other hand, we have investigated the effect of test-retest sessions with players repeating their first test at the end of the day, and found no differences between test scores obtained at the beginning and the end of the test session.

Knee valgus measurements (Paper II-IV)

Although marker-based 3D motion analysis is considered “the gold standard” for assessing lower extremity kinematics and kinetics, with good reliability reported (Ford et al., 2007), there are potential sources of error throughout the different steps when measuring knee kinematics and kinetics. These include marker placement, skin movement artifacts and joint center estimation (Della et al., 2005; Leardini et al., 2005; Chiari et al., 2005; Benoit et al., 2006). To date, the most precise and reliable method for capturing joint kinematics is by X-ray fluoroscopy where the bone pose can be reconstructed from fluoroscopy images (Miranda et al., 2013). However, this is an advanced, expensive and time-consuming method not suitable for large-scale athletic screenings. Another downside of the method is the exposure to radiation.

Frontal plane knee motion represents a multi-plane and multi-joint pattern which not only consists of knee valgus motion, but likely also involves the hip and ankle joint. The rationale for only investigating frontal plane knee kinematics and kinetics in the current studies was based on the fact that a link has been found between knee valgus angles and knee abduction moments and ACL injury in female athletes. Furthermore, a valgus collapse has been identified as a part of the injury mechanism in females. Nevertheless, we acknowledge that other variables than frontal plane kinematics and kinetics would be of interest for assessing ACL injury risk, although marker-based motion analysis would not be the preferred method for obtaining measures of internal/external knee rotation or translation.

Finally, we must keep in mind that the current screening tests have been investigated in a laboratory setting, and we do not know whether the measured knee loads will appear to a similar extent on a football pitch or in other sports-specific settings where the injuries usually occur.

Implications for screening and injury prevention in female football

We have identified the injury patterns in elite female football, suggesting that we need to pay extra attention to knee ligament injuries, as demonstrated in Paper I. These injuries are among the most serious, often leading to absence from participation in training and competition for several weeks and months, emphasizing the importance of injury prevention. Our findings from Paper II further indicate that body mass, previous knee injuries and knee valgus are key factors for the risk of new lower extremity injuries. Moreover, we identified player height, static knee valgus and hip abductor strength as determinants for peak knee valgus angles in Paper IV. Given the fact that knee valgus has been associated with ACL injury in female athletes, tailored and individual training programs aimed at increasing frontal plane knee control and thus reducing knee valgus seems to be essential.

To identify frontal plane knee control and knee valgus in female athletes, our findings in Paper III demonstrated that a real-time observational screening test may be used to identify athletes with high knee valgus angles in a drop jump landing. This test is easy to use and implement in a clinical setting, and represents an effective, low-cost test that can be performed on the training field to identify athletes at risk for injury.

Although the current studies have included elite female football players only, we know from previous research that the injury rates in females, and especially knee ligament injuries, peak during pubertal growth. In other words, screening and injury prevention should be initiated before or during early puberty to have the greatest impact.

Conclusions

I. Prospective individual injury registration using text messaging resulted in more complete recording of injury patterns among elite female football players than standard team medical staff registration, which underestimated the incidence of time-loss injuries substantially. The injury patterns corresponded to previous reports among senior females.

II. Greater BMI was the only factor significantly associated with new lower extremity injuries in elite female soccer players. Greater BMI was associated with thigh injuries and players with lower peak knee valgus angles in a drop jump landing were more likely to sustain a new ankle injury. The history of a previous knee injury was associated with new injuries to the lower leg/foot, whereas neither of the intrinsic factors assessed were associated with knee injuries.

III. Physiotherapists can reliably identify female athletes with high knee valgus angles during a vertical drop jump landing using real-time observational screening, but the screening test scores did not correlate to knee abduction moments. We found high inter-rater agreement between three physiotherapists using the screening test.

IV. Anatomical and neuromuscular characteristics combined explained 13% of the observed variance in peak knee valgus angles in a drop jump landing. Greater measures of body height and static knee valgus, and lower hip abductor strength were associated with greater peak knee valgus angles.

Future research

Although our findings have revealed new knowledge that female football may benefit from, further research is still needed.

1. Individual registrations based on text messaging could replace established methods for monitoring and describing injury patterns in sports. Furthermore, there is a potential for developing even more efficient and accessible tools, including smart phone applications or utilizing social media platforms, which should be considered in future studies.
2. There is a need for new investigations assessing risk factors for injuries by including both intrinsic and extrinsic factors. Given the fact that only seven studies in total have assessed injury risk factors in female football players, of which four included senior players, future risk factor assessments using a multivariate statistical approach are needed. Furthermore, psychosocial factors such as life stressors, mood profiles and coping skills may contribute to injury risk. Taking all these factors into account would provide a more complete picture of an athlete`s injury risk profile.
3. It may be of great importance to include not only elite athletes, but to initiate risk factor studies during early puberty to identify risk factors at an earlier age to implement effective prevention strategies when athletes seem to need them the most.
4. Further development of simple and cost-effective, yet reliable, screening tools to identify female athletes in the high-risk zone for knee injury is needed.
5. Finally, despite the assumption that reducing knee valgus angles and abduction moments during sports specific movements may be advantageous for reducing ACL injury risk, there is a need for further investigations of the predictive value of these measures. We also need to assess the predictive value of existing and new screening tools. Only when such data is available, can we develop and target more effective injury prevention strategies.

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Papers I-IV

Paper I

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Text messaging as a new method for injury registration in sports: A methodological study in elite female football

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Methodological differences in epidemiologic studies have led to significant discrepancies in injury incidences reported. The aim of this study was to evaluate text messaging as a new method for injury registration in elite female football players and to compare this method with routine medical staff registration. Twelve teams comprising 228 players prospectively recorded injuries and exposure through one competitive football season. Players reported individually by answering three text messages once a week. A designated member of the medical staff conducted concurrent registrations of injuries and exposure. Injuries and exposure were compared between medical staff registrations from nine teams and their 159 affiliated players. During the football season, a total of 232 time-loss injuries were recorded. Of these, 62% were captured through individual registration only, 10% by the medical staff only, and 28% were reported through both methods. The incidence of training injuries was 3.7 per 1000 player hours when calculated from individual registration vs 2.2 from medical staff registration [rate ratio (RR): 1.7, 1.2–2.4]. For match injuries, the corresponding incidences were 18.6 vs 5.4 (RR: 3.4, 2.4–4.9), respectively. There was moderate agreement for severity classifications in injury cases reported by both methods (kappa correlation coefficient: 0.48, confidence interval: 0.30–0.66).

Football is a popular sport worldwide, but playing football is associated with a high-injury risk. Based on previous reports, the injury rate among female players ranges between 1 and 7 injuries per 1000 h of training, and 13–24 per 1000 h of match play (Engström et al., 1991; Östenberg & Roos, 2000; Faude et al., 2005; Giza et al., 2005; Jacobson & Tegner, 2007; Tegnander et al., 2008; Le Gall et al., 2008; Hägglund et al., 2009). However, there are substantial variations in injury definitions and registration methods used to describe the injury pattern in football, which may lead to significant discrepancies between the rates reported.

Injury surveillance is a key risk management tool, and establishing reliable and feasible registration systems is a necessary step toward identifying risk factors and implementing preventive strategies. A consensus statement on the conduction of epidemiologic studies in football recommended prospective registrations using a time-loss injury definition for monitoring injuries over time (Fuller et al., 2006). Furthermore, it was recommended that injuries and exposure to training and matches should be reported by a member of the team medical staff.

Studies have been initiated to assess the accuracy and completeness of injury surveillance systems in team sports. Findings from previous studies in youth team handball (Olsen et al., 2006) and football (Emery et al., 2005) suggest that differences in registration methods can explain some of the inconsistencies in the injury rates reported. A recent study in male professional football found that prospective injury surveillance by team medical staff underestimated the incidence of time-loss injuries by at least one-fifth compared with player interviews (Bjørneboe et al., 2011). Similar findings have been described among World Cup alpine skiers, where 91% of the injuries were identified through retrospective athlete interviews compared with 47% by team medical staff registration (Flørenes et al., 2011).

To our knowledge, no studies have used text messaging as a method for prospective injury registration in sports. The aim of this study was therefore to describe the injury pattern in Norwegian elite female football through individual player registration using text messaging and to compare this novel method with routine team medical staff registration.

Materials and methods

Study design and population

All 12 teams in the Norwegian female elite football league (Toppserien) were invited to participate in a prospective injury registration during the 2009 competitive football season (April–November). Players with an A-team contract or players, who were expected to play in the elite league in the following season ($n = 228$), were eligible for participation in this study. They were invited to complete individual registration of injuries and exposure to training and match play throughout the season. In addition, a designated member of the medical staff from each team was asked to conduct a concurrent registration of injuries and team exposure based on traditional methods. These two prospective registration methods were used from April through October to capture all team activities during the competitive football season.

Injury definition and injury form

In accordance with a consensus statement on injury registration in football (Fuller et al., 2006), we used a time-loss injury definition. An injury was recorded if it resulted in a player being unable to take a full part in future football training or match play at least 1 day beyond the occurrence of the injury. The injury was defined as *acute* if it was a result of a sudden, identifiable event and as an *overuse* injury if the onset was gradual and not related to one specific event. Injuries were recorded using an injury form developed according to the consensus statement. We collected information regarding the injury circumstances, such as type of activity (match or training), the playing surface (natural grass or artificial turf), whether the injury was new or recurrent, the injured body part, type of injury, and the specific diagnosis. The injury severity was defined according to the number of days of absence from training and/or match as minimal (1–3 days), mild (4–7 days), moderate (8–28 days), or severe (> 28 days). Players were defined as injured until they could fully participate in regular football training and match play with their team (Fuller et al., 2006).

Individual registration using text messaging (SMS)

All players ($n = 228$) were carefully informed on the data collection procedure prior to the start of the study. They reported injuries and exposure individually using text messaging (SMS) based on an SMS-tracking system (New Agenda Solutions Aps, Copenhagen, Denmark). The registration was conducted on a weekly basis through the automatic generation of three text messages sent every Sunday evening. One SMS was sent out for each of the three questions and the players replied to each of these:

1. How many *minutes* of match play did you do last week? Sum up all matches and report the total number of minutes played.
2. How many *hours* of training did you do last week? Sum up your total hours of football practice, rounding up to nearest full hour.
3. Have you had any injury or illness that has restricted you from full participation in one or more training sessions and/or matches last week? Answer yes or no.

The responses were recorded in a system-generated database. If the players forgot to reply to one or more of the text messages, they automatically received a first reminder after 2 days and a second reminder after another 2 days.

If an injury or illness was reported, the player was contacted by telephone to complete the injury form and collect information regarding the injury circumstances. The injured player was followed-up until she answered "no" on the injury question and was subsequently contacted to establish the correct number of days of absence. Injuries occurring before the start of the injury registration or those occurring in activities other than football training or match were not included. All telephone interviews were conducted by the principal investigator (AN) and the interviews were done within 1–4 days after an injury was reported.

Medical staff registration

Concurrent with the individual SMS registration, a member of the medical staff from all 12 teams reported injuries and exposure on the team level. Prior to the start of the study, they received detailed information and a manual on how to record injuries and exposure. The team physiotherapist performed the prospective injury registration and also recorded team training and match exposure in cooperation with the coach. Injuries were reported using the same injury form as for the individual registration. Exposure data were reported on a monthly basis using a separate form. This exposure form was designed as a calendar, collecting information on type of activity (training or match), playing surface (natural grass, artificial turf, or other), the duration of each session (number of minutes), and the number of players attending each session. The medical staff submitted their exposure and injury forms every month. If necessary, they were reminded by telephone or e-mail by the principal investigator. If information was missing or unclear, we contacted the medical staff members to complete the registration.

Statistics

The information from the individual reports were entered manually into a spreadsheet and transferred to SPSS (PASW Statistics 18, SPSS Inc., Chicago, Illinois, USA). Data were only included in the analysis for those who completed at least the first 5 months of the registration period. Injury patterns are presented as frequencies and injury incidences as the number of injuries per 1000 h of exposure. We compared the rate ratio (RR) between the two methods using a z-test with 95% confidence intervals (CIs) based on a Poisson regression model. The RRs are presented with the medical staff registration as the reference group. Accuracy and completeness were compared between the individual and medical staff registration. Kappa correlation coefficients were calculated for agreement between the two methods (Altman, 1991). Coefficients of 0.81–1.00 are generally interpreted as very good, 0.61–0.80 as good, 0.41–0.60 as moderate, 0.21–0.40 as fair, and less than 0.20 as poor (Altman, 1991). Two-tailed P-values less than 0.05 were considered as statistically significant.

Ethics

The study was part of a large prospective study aimed at investigating risk factors for anterior cruciate ligament (ACL) injuries in elite female football players, which has been approved by the Regional Committee for Medical Research Ethics; South-Eastern Norway Regional Health Authority, Norway; and by the Norwegian Social Science Data Services. All players received additional information about the present study and signed an informed written consent to confirm participation. Players under the age of 18 needed written consent from their parents to be eligible for participation.

Results

Of the 228 players who agreed to participate, 205 (90%) completed the study. Twenty-three players withdrew during the course of the study. Of these, 19 dropped out at the start of the season, two quit playing at the elite level, one sustained an ACL injury early in the season, and one had incomplete registrations throughout the season. Nine out of 12 medical staff members provided complete registrations from April through October. The results are based on the reports from these nine teams, which included 159 players (Fig. 1).

During the 2009 football season, 121 out of 159 players (76%) sustained at least one injury, and a total of 232 unique time-loss injuries were recorded. Of these, 62% ($n = 144$) were reported through the individual registration only, 10% ($n = 23$) by the medical staff only, and 28% ($n = 65$) were reported through both methods (Table 1). The majority of injuries reported were acute (68%; $n = 157$); 92% of these injuries were captured through the individual registration, whereas 40% were recorded by the medical staff. Of the 75 overuse injuries, the corresponding numbers were 87% and 35%, respectively.

More than half of the injuries occurred during football training (58%; $n = 135$), and 90% of these were captured by the individual registration and 33% by the medical staff. The incidence of training injuries was 3.7 (3.0–4.3) per 1000 player hours when calculated from individual reports and 2.2 (1.5–2.8) from medical staff reports (RR: 1.7, 1.2–2.4).

Of the 97 match injuries reported, 91% were captured by the players and 44% by the medical staff. The incidence of match injuries from individual registrations was significantly higher compared with medical staff reports, 18.6 (14.7–22.5) vs 5.4 (3.8–7.0), RR 3.4 (2.4–4.9).

The discrepancy in match incidence between the individual registration and medical staff reports was considerable across all nine teams. Eight out of nine teams had higher training injury incidence through individual registration compared with medical staff reports (Table 2).

The injury pattern described by each of the two registration methods is shown in Table 3. The knee was the

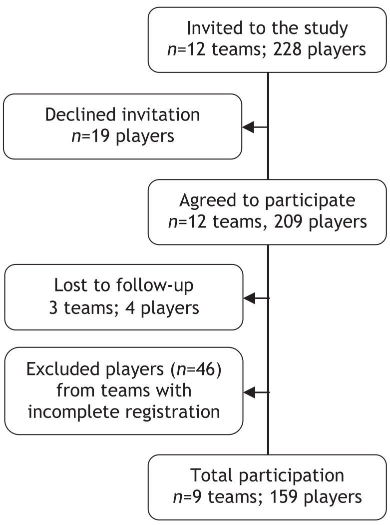

Fig. 1. Flow chart of team medical staff members and players throughout the study.

Table 1. Comparison of injuries reported through individual registration (short message services) only, through medical staff registration only or by both methods ($n = 232$)

	Total (n)	Individual registration (%)	Medical staff registration (%)	Both methods (%)
All injuries	232	62	10	28
Acute injuries	157	61	8	31
Overuse injuries	75	65	13	21
Match injuries	97	56	9	35
Training injuries	135	67	10	23

Table 2. Injury incidence [95% confidence interval (CI)] in training and match reported individually and by the medical staff, and the rate ratio (RR) (95% CI) between the two registration methods

	Individual registration	Medical staff registration	RR*
Team 1			
Match	22.4 (9.2–35.7)	9.7 (3.0–6.4)	0.4 (0.2–1.1)
Training	3.4 (1.5–5.3)	2.9 (0.6–5.3)	0.9 (0.3–2.3)
Total	5.7 (3.3–8.0)	4.9 (2.3–7.4)	0.9 (0.4–1.7)
Team 2			
Match	30.4 (16.4–44.5)	3.2 (–0.4–6.9)	0.1 (0.0–0.4)
Training	4.6 (2.4–6.8)	0.4 (–0.4–1.1)	0.1 (0.0–0.6)
Total	8.2 (5.5–10.9)	1.1 (0.0–2.2)	0.1 (0.0–0.4)
Team 3			
Match	10.1 (1.2–18.9)	3.3 (–0.4–7.0)	0.3 (0.1–0.4)
Training	2.2 (0.4–3.9)	1.0 (–0.4–2.4)	0.5 (0.1–2.3)
Total	3.4 (1.4–5.4)	1.7 (0.2–3.3)	0.5 (0.2–1.5)
Team 4			
Match	22.3 (9.7–34.9)	5.3 (0.1–10.4)	0.2 (0.1–0.7)
Training	4.0 (2.1–6.0)	1.0 (–0.1–2.2)	0.3 (0.1–0.9)
Total	6.1 (3.9–8.3)	1.9 (0.5–3.3)	0.3 (0.1–0.7)
Team 5			
Match	16.8 (6.4–27.3)	7.8 (2.7–12.9)	0.5 (0.2–1.1)
Training	3.9 (2.0–5.7)	3.2 (1.2–5.3)	0.8 (0.4–1.8)
Total	5.4 (3.4–7.4)	4.5 (2.5–6.5)	0.8 (0.5–1.5)
Team 6			
Match	12.1 (2.4–21.8)	6.1 (0.7–11.4)	0.5 (0.2–1.6)
Training	2.9 (1.2–4.7)	2.9 (0.6–5.3)	1.0 (0.4–2.7)
Total	4.0 (2.1–5.9)	3.8 (1.6–6.1)	0.9 (0.4–2.0)
Team 7			
Match	17.7 (6.1–29.2)	11.2 (3.4–18.9)	0.6 (0.2–1.6)
Training	5.2 (2.9–7.5)	5.6 (2.0–9.3)	1.1 (0.5–2.4)
Total	6.6 (4.2–9.1)	7.4 (3.9–10.9)	1.1 (0.6–2.0)
Team 8			
Match	17.1 (5.9–28.3)	0.0 (0.0–0.0)	–
Training	3.8 (1.6–6.1)	1.7 (–0.2–3.7)	0.5 (0.1–1.6)
Total	5.9 (3.3–8.5)	1.1 (–0.1–2.3)	0.2 (0.1–0.6)
Team 9			
Match	16.4 (5.0–27.8)	3.6 (–0.5–7.6)	0.2 (0.1–0.8)
Training	2.6 (1.0–4.1)	2.0 (0.2–3.7)	0.8 (0.3–2.3)
Total	4.1 (2.2–6.0)	2.4 (0.7–4.1)	0.6 (0.3–1.3)
All teams			
Match	18.6 (14.7–22.5)	5.4 (3.8–7.0)	0.3 (0.2–0.4)
Training	3.7 (3.0–4.3)	2.2 (1.5–2.8)	0.6 (0.4–0.8)
Total	5.5 (4.8–6.3)	3.1 (2.4–3.7)	0.6 (0.4–0.7)

*RR obtained from the Poisson model, with individual registration as the reference group.

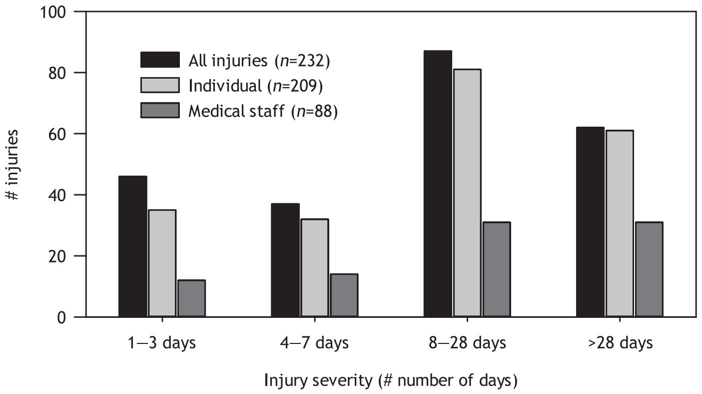

Fig. 2. The severity of the injuries (# days of absence) from individual registration vs team medical staff registration.

Table 3. Injury patterns described through individual ($n = 209$) and medical staff ($n = 88$) registration

Injuries	Individual registration	Medical staff registration	Total
Body Part			
Foot/toes	14 (7%)	6 (7%)	14 (6%)
Ankle	38 (18%)	17 (19%)	43 (19%)
Lower leg	24 (12%)	7 (8%)	25 (11%)
Knee	56 (27%)	25 (28%)	61 (26%)
Thigh	30 (14%)	16 (18%)	35 (15%)
Hip/groin	12 (6%)	7 (8%)	16 (7%)
Trunk	14 (7%)	3 (3%)	16 (7%)
Shoulder/arm	9 (4%)	4 (5%)	10 (4%)
Head/face	12 (6%)	3 (3%)	12 (5%)
Total	209 (100%)	88 (100%)	232 (100%)
Injury type			
Fracture	12 (6%)	7 (8%)	12 (5%)
Joint/ligament	71 (34%)	33 (38%)	80 (35%)
Muscle/tendon	92 (44%)	37 (42%)	104 (45%)
Contusion	20 (10%)	8 (9%)	22 (10%)
Concussion	8 (4%)	2 (2%)	8 (3%)
Skin/laceration	2 (1%)	1 (1%)	2 (1%)
Other	4 (2%)	0 (0%)	4 (2%)
Total	209 (100%)	88 (100%)	232 (100%)

Results are shown as the number of injury cases reported from each of the two methods (*n*, %) and the total number of injuries captured through both methods.

Table 4. Comparison of severity information between individual and medical staff registration

Medical staff	Individual registration				
	1–3 days	4–7 days	8–28 days	> 28 days	Total
1–3 days	1	2	7		10
4–7 days		5	6	1	12
8–28 days		1	10	2	13
> 28 days			1	17	18
Total	1	8	24	20	53

Results are based on 53 out of 65 injuries providing complete information on days of absence.

body part most frequently injured, accounting for 26% of all injuries reported. Individual registrations captured 92% of the knee injuries, whereas the medical staff captured 41%. Muscle and tendon injuries dominated and accounted for 45% of all injuries. Of these, 89% were captured by individual registrations and 36% by medical staff reports. The corresponding figures for joint and ligament injuries ($n = 80$) were 89% and 41%, respectively.

More than one-third of the injuries reported were of moderate severity, leading to absence from training and match for 8–28 days (38%; $n = 87$). Serious injuries causing absence of more than 4 weeks accounted for 62 (27%) of all injuries. The team medical staff captured 50% of these, whereas the players individually reported all but one (98%) of the serious injuries (Fig. 2).

Of the 65 injuries recorded by both methods, a severity classification was missing in 12 medical staff reports. In 33 of the remaining 53 injuries (62%), the severity classification corresponded (Table 4). The medical staff underestimated the severity of the injury in 18 cases, and in two cases the severity was overestimated compared with individual registrations. The kappa correlation coefficients for agreement between the two methods were excellent for both injury location and injury type (1.00), and moderate for injury severity (0.48; 95% CI: 0.30–0.66).

Discussion

The aim of this study was to utilize text messaging as a new method for prospective injury registration in elite female football, comparing this novel method to routine medical staff registration. The main finding was a disquieting discrepancy between the two methods, consistently in favor of the individual registration in terms of the number of injuries that were recorded. Overall, the medical staff missed more than half of all injuries occurring during the 7-month season. This finding is significant, as previous epidemiologic studies have relied on prospective injury registration by team medical staff to describe injury patterns in both female (Engström et al., 1991; Östenberg & Roos, 2000; Faude et al., 2005; Giza et al., 2005; Hägglund et al., 2005, 2009; Jacobson & Tegner, 2007; Tegnander et al., 2008) and male football (Nielsen & Yde, 1989; Árnason et al., 1996; Hawkins & Fuller, 1999; Hägglund et al., 2005; Waldén et al., 2005a, 2005b; Bjørneboe et al., 2012; Ekstrand et al., 2011).

This also means that injury incidence based on the medical staff registration was substantially lower than the incidence calculated from individual registrations. Overall, the medical staff captured only 44% of all match injuries, whereas exposure seemed to be reported in a more consistent manner. The lower match incidence was evident across all nine teams, suggesting that the underreporting by the medical staff was a general finding, not related to one or two therapists failing to comply properly. Furthermore, the current results demonstrate that the underreporting by the medical staff was consistent across all injury types. More than half of the acute injuries and two-thirds of all overuse injuries went unreported by the medical staff, and the capture rate was low for mild as well as severe injuries. As the discrepancies in capture rates were consistent across the injury spectrum, it also means that the injury pattern (proportions of injury type, location, and severity) described from the individual registration are consistent with previous findings in elite female football (Engström et al., 1991; Östenberg & Roos, 2000; Faude et al., 2005; Giza et al., 2005; Jacobson & Tegner, 2007; Tegnander et al., 2008; Le Gall et al., 2008; Hägglund et al., 2009).

This study is the first to utilize text messaging for recording injuries and exposure in sports. Text messaging appeared to be a feasible and convenient tool for registration throughout one football season and, in our case, more exact than team medical staff registration. One of the main advantages of using text messaging was the ease of use for the players, which probably explains the high response rate (90%). We could reach a large player sample without the need for direct personal contact or Internet access, and players could record their data in a few minutes using their mobile phones. In other words, the weekly registration could be completed anywhere, and hence, training camps or travelling did not represent barriers for responding to the text messages. In this way, we could get individual and accurate data on a weekly basis, which reduced the risk of recall bias.

Previous studies have compared different methods for the registration of sports injuries, and it seems clear that injury incidence does not just depend on the injury definition used, but is highly dependent on who records the injuries, how and when. One study investigated the validity of prospective injury surveillance in youth soccer players by comparing weekly exposure sheets provided by a team designate to injury report forms completed by a team therapist (Emery et al., 2005). There was an inconsistency in time loss calculated from the exposure sheets and the days of absence registered on the injury report forms, and the team therapist underreported the severity in one-third of all injuries. In another study, monthly coach reporting was found to give more precise estimations of injury severity than prospective match reporting by scorekeepers among youth team handball players (Olsen et al., 2006). In contrast, when comparing two parallel registrations among high school athletes, coaches submitted only 37% of the expected exposure reports compared with 98% of athletic trainers (Yard et al., 2009), and there was low agreement for diagnosis, as well as for time lost from sport participation (63% and 55% of pairs, respectively). Similar to our findings, a recent study in youth female football found that Internet surveys based on individual parent reports captured more injuries than did reporting by athletic trainers (85% vs 63%, respectively) (Schiff et al., 2010). A substantial discrepancy was also found between player registration and medical staff reports among male professional football players (Bjørneboe et al., 2011). An established injury surveillance system based on prospective medical staff registration was compared with retrospective player interviews. The medical staff registration underestimated injury incidence by one-fifth. However, it should also be noted that one-third of the injuries occurring during the 3-month recall period were not reported by the players, indicating that recall bias is substantial when conducting retrospective interviews. Nevertheless, retrospective athlete interviews among World Cup alpine skiers covering one competitive season captured 91% of injuries, compared with only 47% from prospective recording by team medical staff (Flørenes et al., 2011). Still, in general, retrospective injury recording is associated with recall bias and, therefore, may lead to an underestimation of injury rates (Junge & Dvorak, 2000). As both registration methods in our study were conducted in a prospective manner with weekly or monthly reports for individual and medical staff registration, respectively, recall bias should be less of a factor. However, it may have been more of a factor with the medical staff reporting; their reports were accomplished monthly, although they were expected to record injuries as they happened.

A number of other factors could also explain the large discrepancy observed between individual and medical staff reporting in our study. In most cases, an injured player will contact the team physiotherapist for an examination and follow-up to increase her chances of returning to play as soon as possible. However, some players may wish to hide injuries from their physiotherapist or coach to be able to continue playing, yet may still have reported their injury through the individual registration. Being injured could potentially influence their position within the team and their chances to start the next match. Furthermore, the low capture rate from the medical staff registration may be explained by their limited presence at team training sessions during a regular week. There are financial limitations in the female elite league, and access to medical staff is a question of priority. On average, the team physiotherapists were present at one or two team training sessions per week, and as they did not attend every training session, this may have limited their possibility for capturing all injuries. On the other hand, if this were the case, it would most likely affect the mild and minor injuries, leading to only a few days of absence. However, as our results show, the cases most often missed by medical staff were the serious ones, and 50% of injuries leading to more than 4 weeks of time loss were not captured. Moreover, medical staff underestimated the injury severity in 18 out of 53 cases. Thus, their reports would therefore suggest that injuries in elite female football players are less severe than they actually are. Motivational issues in relation to financial limitations could also be a factor affecting the low registration rate among the medical staff members. Much of their work is based on voluntariness with restricted economical compensations. Even if they were positive and cooperative, participation in the study may have represented an extra burden, which affected their compliance throughout the football season. Finally, the medical staff members were aware of the concurrent player registration. This may have affected their accuracy and responsiveness during the season. However, they were thoroughly informed of the aims and procedures of the study prior to the season and we emphasized that their reports were independent of the individual player registration.

When interpreting the results from this study, there are a few limitations to be considered. First, 3 out of 12 medical staff members from the elite league had incomplete registrations and their teams, with 46 players, could not be included in the analysis, even if they completed the individual SMS registration. However, even if we assume that motivation and ability may vary between therapists, the discrepancy between individual and medical staff registration was quite consistent between teams, and there is no reason to believe that the excluded teams would have done any better than those included. Second, a limitation of the system is that the players had to bear the costs for the three weekly text messages. Although there were no negative reactions or complaints, we randomly chose one player with complete registrations each of the 7 months who received a gift certificate at a face value of NOK 1000 to increase their motivation. For the medical staff, we did not offer any incentives for conducting the registrations, other than encouraging them to provide complete registrations with the aim of identifying their team's injury profile. Even if the medical staff members were positive and cooperative, participation in the study represented an extra burden, which may have affected their motivation.

In conclusion, prospective individual injury registration using text messaging resulted in a more complete recording of injury patterns among elite female football players than standard team medical staff registration, which underestimated the incidence of time-loss injuries substantially. Thus, weekly registrations using text messaging appeared to be an effective method for recording injuries and exposure individually in team sports and should be considered in future injury surveillance studies.

Perspectives

The present study revealed promising findings regarding the implementation of a novel method for injury registration in team sports. Text messaging appeared to be a feasible and reliable tool for registration of injuries and exposure throughout one football season and, in our case, resulted in much more complete data than team medical staff registration. As prospective medical staff registration represents the current gold standard for injury surveillance, our results suggest that this should be reconsidered. Individual registration based on text messaging could replace established methods for monitoring and describing injury patterns in sports. Furthermore, there is a potential for developing even more efficient and accessible tools, including smartphone applications, as well as utilizing modern communicative methods such as Skype, Facebook, or Twitter.

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

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Paper II

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Paper IV

Anatomical and neuromuscular determinants for peak knee valgus angles in vertical drop jumps

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Abstract

Background: Excessive knee valgus has been associated with anterior cruciate ligament (ACL) injury in female athletes, but the potential contribution of anatomical and neuromuscular characteristics on knee valgus is not completely understood.

Purpose: To investigate the relationship between anatomical and neuromuscular characteristics combined and peak knee valgus angles in a vertical drop jump landing.

Study design: Cross-sectional.

Methods: Norwegian elite female football players participated in preseason screening tests from 2009 through 2012. These included marker-based three-dimensional (3D) motion analysis of a drop jump landing, anatomical measures (height, static knee valgus, femur and tibia length, knee laxity and foot pronation) and muscle strength assessments (quadriceps, hamstrings and hip abductors). We investigated the combined relationship between anatomical and neuromuscular characteristics and peak knee valgus angles in the contact phase of a drop jump landing using simple and multiple linear regression analyses. We further assessed the relative importance of each of the independent factors on peak knee valgus angles.

Results: A total of 279 players were included (age: 21 ± 4 years; height: 167 ± 6 cm; body mass: 63 ± 7 kg). Anatomical and neuromuscular characteristics combined explained 13% of the variance in peak knee valgus angles ($p<0.001$), with height, static knee valgus and hip abductor strength being significant determinants. An increase in height or static knee valgus by 1 SD corresponded to an increase in peak knee valgus of 0.8°, whereas 1 SD increase in hip abductor strength decreased knee valgus by 0.3°.

Conclusion: The multiple regression model with anatomical and neuromuscular characteristics combined explained 13% of the variance in the observed peak knee valgus angles. Greater body height and static knee valgus, and lower hip abductor strength was associated with greater peak knee valgus angles in a drop jump landing.

Clinical relevance: A better understanding of the underlying factors that contribute to high knee valgus angles could help identifying female athletes who may have an increased risk of knee injury and thus would benefit from injury prevention training.

Key terms: female; football; anterior cruciate ligament; biomechanics; screening

What is known about the subject:

- Frontal plane knee kinematics and kinetics have been associated with ACL injury in female athletes.
- Gender differences in motion patterns during dynamic tasks have been documented, with females displaying greater measures of knee valgus compared to males.
- Neuromuscular training programs targeting improved frontal plane knee control and thereby reduced knee valgus, have been found to reduce knee injury rates.
- Anatomical alignment and neuromuscular characteristics have been related to knee kinematics in a drop jump landing in separate investigations, but not combined.

What this study adds to existing knowledge:

- The current study investigated how anatomical and neuromuscular characteristics combined contribute to knee valgus in a drop jump landing task.
- Greater player height and static knee valgus, and lower hip abductor strength were associated with greater peak knee valgus angles.

Introduction

Anterior cruciate ligament (ACL) injuries represent a major concern in sports and constitute a serious problem in terms of a long absence from sports and an increased risk for early osteoarthritis.[32,39,52] Excessive dynamic knee valgus has been suggested as being contributory to the ACL injury mechanism,[27,29,40] and is visually associated with a valgus collapse of the knee during dynamic tasks. It has also been reported that greater dynamic knee valgus and knee abduction loads may be predictors of ACL injury in female athletes.[21] Moreover, neuromuscular training programs focusing on improving frontal plane knee control and reducing knee valgus have been proven effective.[36,38] Further knowledge on how to improve and individualize these programs could make them less time-consuming and more acceptable to athletes and coaches, and hence increase the preventive effect.[2]

Given the relationship between knee valgus loads and knee injuries, screening during dynamic tasks, such as the vertical drop jump, has been promoted to identify athletes at risk for knee injury.[14,16,18,19,21,22,34,35,41,48,49] However, the underlying causes for an athlete to display greater knee valgus is not completely understood, but may be important for targeting our injury prevention efforts. It is likely that a combination of anatomical and neuromuscular characteristics influence knee joint biomechanics, but there is a lack of knowledge as to what extent these factors in combination contribute to knee valgus.

Lower extremity alignment factors may influence knee loads, and Nguyen *et al*[37] identified a relationship between static lower extremity alignment characteristics and hip muscle activation and functional knee valgus during a single-leg squat. Less anterior pelvic tilt, and greater femoral anteversion, frontal plane knee valgus angle and navicular drop were found to predict greater hip internal rotation excursion and knee external rotation excursion. In another investigation,[47] greater hip adduction and knee valgus during a drop jump landing were found in females displaying greater transverse plane knee laxity. The relationship between anterior knee laxity and knee valgus, however, has not been assessed. Interestingly, Shultz *et al*[45] found that participants with greater anterior knee laxity were more likely to display greater hip anteversion and greater navicular drop, which are factors likely to influence frontal plane knee kinematics.
Dynamic stability of the knee joint is provided by surrounding muscles, and lower extremity muscle strength is likely an important contributor to knee control during dynamic tasks.[11] As such, neuromuscular deficits may compromise the stability of the hip or knee during sport-specific tasks, resulting in faulty dynamic alignment of the lower extremity and potentially

increase the risk of injury. However, there are conflicting results with regards to the relationship between muscle strength and frontal plane knee kinematics. Some investigators have identified hip adduction motion as a substantial contributor to excessive dynamic knee valgus during single-leg tasks, [24,54] suggesting that hip abductor strength may be related to knee valgus. Moreover, lower hip abductor strength has been associated with greater knee valgus motion in female athletes during landing [26,53] and squatting tasks [3,11,55]. In contrast, other investigators found no association between hip abductor strength and frontal plane knee motion during similar tasks.[4,25,30] One study even reported the opposite findings, i.e. a positive correlation between hip abductor strength and knee valgus.[24] Furthermore, conflicting results have been reported for the effect of strength training protocols on frontal plane biomechanics, [20,36,43] indicating that the contribution of lower extremity muscle strength on knee valgus remains somewhat unclear.

Increased awareness on how anatomical and neuromuscular characteristics collectively influence peak knee valgus angles may help clinicians improve training protocols to prevent non-optimal movement patterns and reduce injury risk. This combined relationship has been investigated for single-leg squats only, not during a vertical drop jump landing, and few studies have included a comprehensive set of screening tests. The purpose of this study was to investigate the combined relationship between anatomical and neuromuscular characteristics and peak knee valgus angles in a vertical drop jump landing. We therefore aimed to assess whether greater measures of body height, femur and tibia length, anterior knee laxity and foot pronation, and lower quadriceps-, hamstrings- and hip abductor strength could predict greater peak knee valgus angles.

Materials and methods

Study design and participants

The current study is based on data from a prospective cohort study investigating risk factors for non-contact anterior cruciate ligament (ACL) injuries in elite female football players. All players in the Norwegian female elite league were invited to a comprehensive set of preseason screening tests in 2009, and new players in the elite league were enrolled in the study through the subsequent seasons (2010-12). Players with an A-team contract who were expected to play in the elite league the following season were eligible for participation, and 350 players were tested across four seasons. We excluded players with incomplete data from the 3D motion analysis due to injuries or pain (n=18) or technical problems (n=31), as well as players who did not complete all anatomical or strength tests (n=22). Thus, the final sample counted 279 players from all four seasons (2009-12).

Test procedures

All screening tests were conducted in February and March, before their competitive season (2009-12) at the Norwegian School of Sport Sciences, Oslo. Each player spent about 7 h to complete all tests throughout one day of testing, including warm-up and a lunch break. The data collection procedures were the same for each of the 4 seasons, and included data from the following tests:

Knee kinematics in a vertical drop jump landing

We assessed peak knee valgus angles in the landing (deceleration phase) of a vertical drop jump using skin marker-based three-dimensional (3D) motion analysis. This method is considered the gold standard for assessing knee joint kinematics in a drop jump landing, with good to excellent reliability reported (ICC 0.62-0.99).[17] All players wore indoor football or running shoes, shorts and a sports bra, and 35 reflective skin markers were attached over anatomical landmarks on the legs, arms and torso (Figure 1). For each year of testing, one medical student or physiotherapist palpated the anatomical landmarks and placed the markers on all players to ensure standardization.

Eight infrared cameras (ProReflex, Qualisys, Gothenburg, Sweden) were used to capture the kinematic data at 240 Hz, while ground reaction forces and the centre of pressure were recorded from two force platforms collecting at 960 Hz (AMTI LG6-4-1, Watertown, Massachusetts, USA). Prior to the vertical drop jump, the players completed a static calibration trial to determine the anatomical segment coordinate systems.

The test procedure was standardized for all players, including a warm-up session of 10 min cycling with moderate load on a stationary bike, 10 jumps and 10 sideways shuffle jumps. Starting from a 30-cm high box, they were instructed to drop off the box, immediately followed by a maximal vertical jump. Participants were allowed up to three practice trials, and at least three successful trials were collected. For a trial to be considered successful the participants had to land with one foot on each of the two adjacent force platforms and all reflective markers had to be visible for the cameras throughout the jump.

Marker trajectories were identified with the Qualisys Track Manager (Qualisys, Gothenburg, Sweden), and skin marker trajectory and force data were low-pass filtered with a 15 Hz smoothing spline.[56] The contact phase was defined as the period where the unfiltered vertical ground reaction force exceeded 20 N. Knee joint frontal plane kinematics were obtained using custom Matlab scripts (Mathworks Inc., Natick, MA, USA), as described in a previous study.[28] Anatomical coordinate systems of the thigh and shank were determined from the static calibration trial. We defined the vertical axis in the direction from distal to proximal joint center. The antero-posterior axis was defined perpendicular to the vertical axis, while the third axis was the cross product of the vertical and antero-posterior axis. From the static calibration trial we defined their zero posture and measured static knee valgus/varus alignment, as well as femur and tibia length. Femur length was defined as the distance between the hip joint center[5] and the knee joint center,[12] whereas tibia length was defined as the distance between the knee joint center and the ankle joint center.[15]

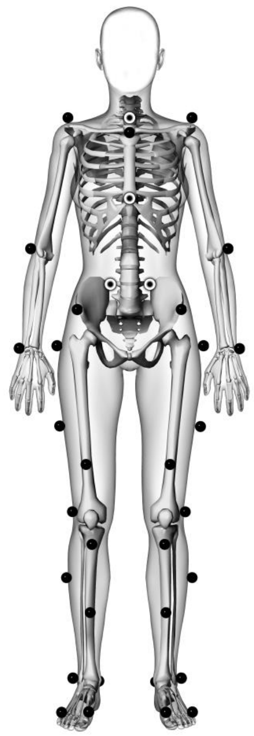

Figure 1. The marker set.

Anthropometrics

To estimate inertia parameters, we obtained anthropometric measures of all players, including 46 measures of segment heights, perimeters and widths.[58,59] Their body mass was collected from a questionnaire obtaining information on demographic data.

Knee joint laxity

We measured anterior-posterior knee joint laxity using a KT-1000 arthrometer (MEDmetric Corp, San Diego, California, USA) with the players supine on an examination table. With the knees flexed to 25 ±5° over a thigh bolster, we applied posteriorly directed forces to the tibia to establish a zero reference point, followed by an anteriorly directed force of 134 N to measure anterior knee joint laxity (mm). We recorded the maximal value out of two trials for both legs. The reliability of KT-1000 measurements by experienced raters has been shown to be good (ICC 0.79).[7]

Foot pronation

We assessed foot pronation using the navicular drop test, measuring the difference in navicular height (mm) from standing with the subtalar joint in neutral position to the standing relaxed foot position.[46] With the players barefoot on a hard and elevated surface, we marked the most prominent aspect of the navicular bone. The distance from the navicular bone to the floor in neutral and relaxed position was measured with a ruler. For this test, intra-rater and inter-rater reliability has been reported as moderate to very good (ICC 0.91-0.97 and 0.56-0.76, respectively).[46]

Quadriceps and hamstrings strength

To assess maximal isokinetic quadriceps and hamstrings strength we used a Technogym REV 9000 dynamometer (Gambettola, Italy), with a test range of motion of 90° through 15° of knee flexion and an angular velocity of 60°/s. The dynamometer was adjusted individually and we used two belts for fixation of the pelvis and torso. We used a standardized test protocol starting with a 5-min warm-up on a cycle ergometer with moderate load, and recorded their peak torque (Nm) for concentric quadriceps and hamstrings strength on both legs independently. Isokinetic muscle strength testing has been found reliable for assessing muscle force, with ICCs of 0.81-0.97.[8]

Hip abductor strength

We measured maximal hip abductor strength using a handheld dynamometer (Hydraulic Push-Pull Dynamometer, Baseline® Evaluation instruments, White Plains, NY, USA). With the player supine, the pelvis was fixed to the examination table using a fixation belt and we placed the dynamometer 2 cm proximally to the lateral malleolus. No support from hands or the opposite leg was allowed, and we applied resistance in a fixed position for 3-5 s until maximal isometric contraction was reached. The players were allowed two trials and we recorded their maximum trial (kg) for both legs. Similar procedures have been established as reliable for assessing hip abductor strength in athletes (ICC 0.84-0.97).[50,51]

Statistical analyses

Data were analysed using IBM SPSS Statistics Data Editor, version 21 (IBM Corporation, Somers NY, USA) and STATA Version 12.0 (StataCorp, College station, Texas, USA). Descriptive data are presented as means ± standard deviations (SD), and data are separated by dominant and non-dominant legs. From the 3D motion analysis we included peak knee valgus angles during the contact phase of the vertical drop jump. Peak knee valgus angles were averaged across three trials for both the right and the left knee, providing separate peak values for each leg for all players. From all strength tests, their peak values were recorded and used for analysis.

Pearson`s correlation coefficients were calculated to control for inter-correlations between the independent variables and decide upon inclusion in the multiple regression model. We calculated correlations for dominant and non-dominant legs separately. Correlation coefficients of 0.81 to 1.00 were interpreted as being very good, 0.61 to 0.80 as good, 0.41 to 0.60 as moderate, 0.21 to 0.40 as fair, and less than 0.20 as poor.[1] We set a cut-off at 0.70, and due to high inter-correlations for body height, femur and tibia length, only height was included in the final model.

We used simple linear regression analyses to determine the individual relationships between all anatomical and neuromuscular factors (independent variables) and peak knee valgus angles (dependent variable) during a drop jump landing. Unstandardized regression coefficients were calculated for dominant and non-dominant legs separately. Multiple linear regression analyses were used to investigate the amount of variance in peak knee valgus angles explained by anatomical and neuromuscular factors combined, with standardized regression coefficients reported. All legs were included in the regression model (n=558), clustered by player-ID to account for the relationship between left and right legs for each player. To further examine the relative importance of the independent factors in the multiple regression analysis, we calculated the effect of changing each of the anatomical and neuromuscular factors by 1 SD, keeping the others constant. This was done by multiplying the standardized regression coefficients with the SD of the corresponding factors, divided by mean valgus angles for all legs combined. One SD is considered a measure of the normal variation between subjects and shows the potential for variation and change in the intrinsic factors included in the current study. For the final analyses the significance level was set at $p < 0.05$.

The study was approved by the Regional Committee for Medical Research Ethics; South-Eastern Norway Regional Health Authority, and by the Norwegian Social Science Data Services, Norway. All players signed a written informed consent form. Players under the age of 18 needed written consent from their parents to be eligible for participation.

Results

Player characteristics

The total sample included 279 players (age: 21 ± 4 years; height: 167 ± 6 cm; body mass: 63 ± 7 kg). Means and standard deviations for all variables, separated by dominant and non-dominant legs, are presented in Table 1. Player height, femur and tibia length were highly correlated ($r>0.70$) and correlations between strength variables ranged from $r=0.19$ to 0.70 (Table 2).

Table 1. Anatomical and neuromuscular test variables presented as mean ± SD and range, separated by dominant (dom) and non-dominant (non-dom) legs.

Test variables	**Dom (mean ± SD)**	**Non-dom (mean ± SD)**	**Range**
Peak knee valgus (°)	4.5 ± 5.4	5.7 ± 5.4	-8 - 21
Static knee valgus (°)	-0.5 ± 3.1	-0.7 ± 2.8	-9 - 6
Femur length (mm)	41.2 ± 2.0	41.5 ± 2.0	35 - 46
Tibia length (mm)	40.5 ± 2.3	40.4 ± 2.3	33 - 46
Knee joint laxity (mm)	6.5 ± 1.7	7.0 ± 1.9	3 - 13
Foot pronation (mm)	4.8 ± 3.6	4.9 ± 3.4	-5 - 15
Quadriceps strength (Nm)	146.8 ± 25.0	145.9 ± 26.5	69 - 224
Hamstrings strength (Nm)	88.3 ± 14.3	85.3 ± 14.5	31 - 149
Hip abductor strength (kg)	13.3 ± 2.9	13.6 ± 2.8	6 - 23

Table 2. Correlations (r) between anatomical and neuromuscular variables, presented for the dominant (upper right, grey) and non-dominant (bottom left, white) leg

	Height	**Body mass**	**Femur length**	**Tibia length**	**Static valgus**	**Knee laxity**	**Foot pronation**	**Quadriceps**	**Hamstrings**	**Hip abductor**
Height	1	0.559*	0.735*	0.718*	-0.011	-0.035	-0.032	0.331*	0.335*	0.046
Body mass	0.559 *	1	0.275*	0.434*	-0.001	-0.059	-0.076	0.535*	0.530*	0.211*
Femur length	0.749*	0.272*	1	0.559*	-0.064	-0.046	-0.106	0.194*	0.182*	-0.138*
Tibia length	0.717*	0.443*	0.596*	1	-0.134*	0.159*	0.107	0.342*	0.363*	0.034
Static valgus	-0.015	0.024	-0.508	-0.139*	1	-0.176*	0.009	-0.096	-0.114	0.064
Knee laxity	0.008	-0.034	-0.002	0.119*	-0.306*	1	0.173*	0.045	0.024	0.040
Foot pronation	-0.018	-0.005	-0.096	0.101	-0.022	0.103	1	-0.096	-0.081	-0.057
Quadriceps	0.341*	0.537*	0.171*	0.319*	-0.068	-0.065	0.009	1	0.690*	0.238*
Hamstrings	0.368*	0.545*	0.203*	0.359*	-0.106	0.044	0.067	0.695*	1	0.244*
Hip abductor	0.095	0.240*	-0.061*	0.012	0.044	-0.037	-0.003	0.188*	0.214*	1

*Correlation is significant at the $p<0.05$ level.

Determinants for peak knee valgus angles

The strongest independent association between anatomical and neuromuscular factors and peak knee valgus angles was found for static knee valgus, with unstandardized regression coefficients of 0.56 and 0.48 for dominant and non-dominant legs, respectively (Table 3). The multiple regression model combining anatomical and neuromuscular factors explained 13% of the variance in peak knee valgus angles ($p<0.001$). Player height, static knee valgus and hip abductor strength were the only significant factors of the model, with static knee valgus being the strongest predictor of peak knee valgus angles ($\beta=0.27$) (Table 4).

Table 3. Independent anatomical and neuromuscular variables as determinants for peak knee valgus angles using simple linear regression analyses. Unstandardized coefficients are presented for dominant and non-dominant legs.

	Dominant leg			Non-dominant leg		
Test variables	**Coefficient [a]**	**SE [b]**	**P-value**	**Coefficient [a]**	**SE [b]**	**P-value**
Height	0.317	0.110	0.004*	0.133	0.112	0.236
Static knee valgus	0.559	0.104	≤0.001*	0.482	0.117	≤0.001*
Femur length	-0.306	0.234	0.193	-0.120	0.249	0.630
Tibia length	-0.018	0.203	0.931	-0.236	0.206	0.253
Knee laxity	-0.143	0.183	0.435	-0.132	0.176	0.453
Foot pronation	-0.001	0.090	0.988	-0.154	0.094	0.103
Quadriceps strength	-0.010	0.017	0.564	-0.027	0.017	0.112
Hamstrings strength	-0.027	0.031	0.383	-0.013	0.031	0.684
Hip abductor strength	-0.230	0.112	0.040*	-0.243	0.116	0.037*

[a] Unstandardized coefficients.
[b] SE, standard error.
*Relationship is significant at the $p<0.05$ level.

Table 4. Anatomical and neuromuscular factors as predictors for peak knee valgus angles using multiple regression analyses.

Test variables	**β coefficient** [a]	**SE** [b]	**P-value**
Height	0.146	0.042	≤0.001*
Static knee valgus	0.267	0.079	≤0.001*
Knee laxity	-0.026	0.124	0.539
Foot pronation	-0.030	0.065	0.464
Quadriceps strength	-0.059	0.011	0.274
Hamstrings strength	-0.102	0.021	0.075
Hip abductor strength	-0.115	0.076	0.004*

[a] Standardized coefficients.
[b] SE, standard error.
*Relationship is significant at the $p<0.05$ level.

The relative importance of the different anatomical and neuromuscular factors on peak knee valgus angles is presented in Figure 2. An increase of 3° of static knee valgus or a 6-cm increase in player height corresponded to a 0.8° increase in peak knee valgus angles. Increasing hip abductor strength by 2.8 kg would decrease peak knee valgus angles by 0.3°.

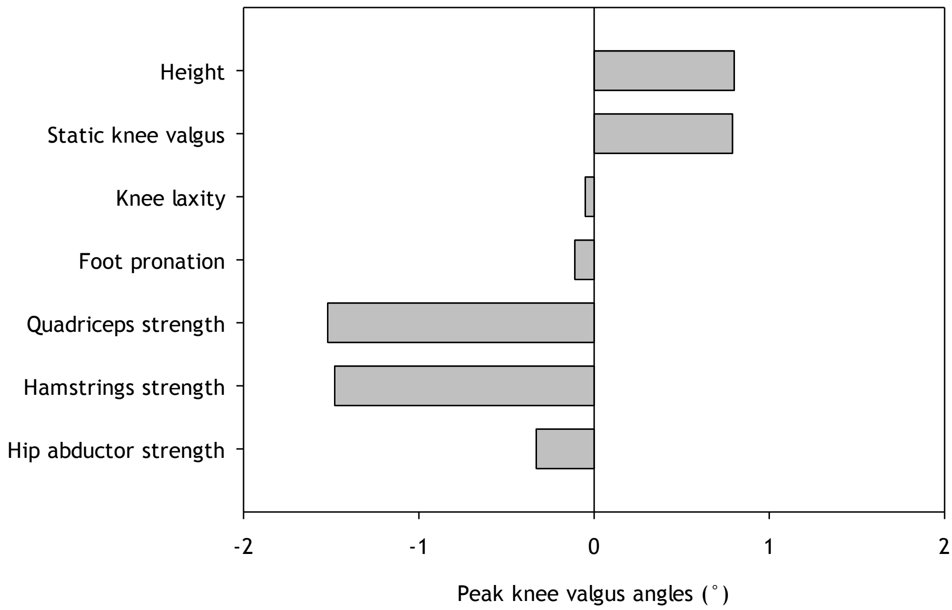

Figure 2. Effect on peak knee valgus angles (° change) by increasing each independent factor 1 SD and keeping the others constant.

Discussion

The current study is the first to investigate the combined effect of anatomical and neuromuscular characteristics on peak knee valgus angles in a drop jump landing task, and we found that these variables collectively explained 13% of the variance in the observed knee valgus angles. Based on the poor ability of our combination of variables to explain peak knee valgus, 87% of the variance remains to be accounted for by other factors than those included in our model. As such, there are likely other anatomical alignment variables, neuromuscular or biomechanical characteristics that contribute to knee valgus. *Post hoc* analyses assessing the effect of including anatomical and neuromuscular factors in two separate multiple regression models confirmed this assumption; these two models explained 11% and 3% of the variance, respectively.

Static knee valgus angles, player height and hip abductor strength were the only factors significantly associated with peak knee valgus angles in a drop jump landing. Clinically, it seems reasonable that static knee valgus and greater body height, and therefore likely longer lever arms of the lower extremities, in combination with reduced hip abductor strength would contribute to greater knee valgus angles. However, the relative effect of these variables was low. Based on our findings, an athlete displaying 1SD off the mean for measures of height, static valgus and hip abductor strength would change peak knee valgus by 1.9°, whereas being 1SD off the mean on all variables would correspond to a 5° change in peak knee valgus. The clinical relevance of a 5° change is likely of importance as such a change could provide a substantial contribution to lower extremity alignment and knee valgus load during dynamic tasks. The relevance of two degrees, however, may be questioned.

Anatomical characteristics

Two of the anatomical characteristics were identified as predictors for peak knee valgus; static knee valgus and player height. Although both of these are considered non-modifiable, increased awareness on how they influence knee valgus in dynamic tasks would be beneficial for identifying athletes in the high-risk zone and thereafter target strength and stability exercises that may prevent injuries. The strongest predictor of our regression model was static knee valgus. However, even though static valgus was significantly associated with peak knee valgus, the standardized regression coefficient was low. Furthermore, the relative importance of changing this variable was limited, as an increase of 3° in static valgus corresponded to an increase in peak knee valgus angles of 0.8° only. Nevertheless, this study revealed trends similar to previous investigations showing that players displaying greater knee valgus in neutral standing are more likely to display a similar pattern during dynamic tasks.[37] In accordance with our findings, Nguyen *et al* [37] identified static lower extremity alignment characteristics, including greater knee valgus alignment, greater hip internal rotation and less anterior pelvic tilt, to be related to components of a functional valgus collapse during a single-leg squat in female athletes. In contrast, Pantano *et al* [42] found no association between static knee valgus alignment and dynamic knee valgus angles during a single-leg squat. However, these studies investigated single-leg squats, whereas we included a vertical drop jump task, which may reveal different patterns. We also identified taller players to be more likely to display greater peak knee valgus in the drop jump landing. This was not surprising, considering that player height was correlated to femur and tibia length ($r>0.70$), and the fact that longer lever arms may generate greater loads on the knee joint. Combined with a static knee valgus posture, it is reasonable that these factors would contribute to knee valgus in a dynamic task.

Increased pronation of the foot may stress medial structures of the lower limb and alter biomechanics of the lower extremity, and thereby potentially contribute to knee injury risk. Moreover, greater foot pronation has also been found in subjects with a history of previous ACL injury compared to non-injured controls.[33,57] However, we identified no association between measures of foot pronation and peak knee valgus angles. The potential relationship between anterior knee laxity and knee valgus in a drop jump task has not been evaluated in previous reports, and we found no relationship between these factors in the current study. Interestingly, Shultz *et al* [47] found a relationship between transverse plane knee laxity, hip adduction and knee valgus motion during a drop jump landing. In their investigation, females displaying greater knee joint laxity landed with greater hip adduction and knee valgus in a drop jump, suggesting that transverse plane laxity contributes to frontal plane knee motion.

Neuromuscular characteristics

The third most important predictor of our regression model was hip abductor strength. Players with reduced strength of the hip abductors displayed greater knee valgus angles, suggesting a knee problem may have a proximal origin. In contrast to non-modifiable anatomical characteristics, an increase in muscle strength can easily be targeted through strength training protocols and should be considered by clinicians. Furthermore, from a clinical point of view, weakness of the hip abductor muscles may permit increased adduction and internal rotation of the femur and diminished control of dynamic knee valgus. However, the relative importance of this variable was rather low, as an increase in abductor strength by 2.8 kg (1SD) would reduce peak knee valgus by 0.3° only.

There are inconsistencies in the literature with respect to the relationship between lower extremity muscle strength and knee valgus. In a recent systematic review [9] of studies investigating the link between hip strength and knee valgus, only four out of 11 studies found evidence that participants with weaker muscle strength demonstrated greater knee valgus. Due to variability in study methodology and conflicting findings, no definite conclusions could be drawn in this review. These studies included small sample sizes, ranging from 13 to 76 participants, which are substantially lower than the number of participants included in the current study. Furthermore, there were large variations in study population, choice of strength measurements and tasks evaluated. Only one study assessed a vertical drop jump task, whereas the remaining ten evaluated single-leg tasks.

In accordance with our findings, previous reports have identified a relationship between lower hip abductor strength and greater knee valgus in drop jump landings [26,53] and single leg squats.[11,55] In contrast, other investigations found no correlations between hip strength and knee valgus during a single-leg landing [30,44] or single-leg squats. [23] Surprisingly, Hollman *et al* [24] reported a positive correlation between hip abductor strength and knee valgus angles during a single-leg step-down, indicating greater measures of knee valgus in subjects with greater hip muscle strength. However, they included 20 participants only, and knee valgus angles were estimated from 2D video analyses. Their conclusions should therefore be interpreted with caution. Nevertheless, we should keep in mind that in contrast to the current study, these investigators assessed knee valgus during single-leg tasks of varying difficulties, which may provoke different landing patterns compared to a vertical drop jump landing. Inconsistent findings from previous studies are likely related to small samples and large variability in participants included. We included a large sample size and identified a significant, but weak relationship between hip abductor strength and knee valgus.

Finally, we found no statistically significant relationship between maximal strength of the quadriceps and hamstrings and peak knee valgus angles. This finding is in accordance with a previous report, [53] where maximal squat strength did not correlate with knee valgus angle in a vertical drop jump landing in female football players. Despite the tendency towards reduced valgus angles with increased strength of the quadriceps and hamstrings, our non-significant findings showed that these muscles were not important for frontal plane knee control.

Methodological considerations

In the current study, we included a large and homogenous sample of female athletes and assessed the combined potential of anatomical and neuromuscular factors to predict knee valgus in a drop jump landing. However, there are some potential limitations to the study. First, the independent variables included in the multiple regression model only explained 13% of the variance in the observed peak knee valgus angles. This indicates that other characteristics than those included in our investigation provide greater contributions to peak knee valgus angles. We believe that we included the most important measures of anatomical alignment and muscle strength, but acknowledge that other factors, such as neuromuscular control may be of great relevance for knee valgus motion. Second, although marker-based 3D motion analysis is considered "the gold standard" for assessing lower extremity kinematics, there are potential sources of error when measuring knee valgus, including anatomic landmark identification, skin movement artifacts and joint center estimation.[6,10,13,31] This may also be the case for the independent variables included. On the other hand, our large sample size including 279 athletes reduces the potential effect of measurement errors, and our estimates are therefore likely to be more robust than previous estimates. Finally, the predictive value of knee valgus angles, as well as anatomical and neuromuscular characteristics with ACL injury as the outcome needs to be further investigated.

Conclusion

In conclusion, the multiple regression model with anatomical and neuromuscular characteristics combined explained 13% of the variance in the observed peak knee valgus angles. Greater body height and static knee valgus, and lower hip abductor strength were associated with greater peak knee valgus angles in a drop jump landing.

Implications

The current study found player height, static knee valgus and hip abductor strength to be associated with peak knee valgus angles. Although the anatomical characteristics are non-modifiable in nature, a better understanding of the underlying factors that may influence injury risk is beneficial for the identification of athletes at increased risk of injury and thus for developing more targeted injury prevention protocols. Considering our results in light of previous findings, clinicians should assess alignment of the entire lower extremity when screening for knee valgus and injury risk, as relationships between these factors are also dependent on what other factors that are accounted for.

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Appendix 1

Approval from the Regional Committee for Medical Research Ethics

UNIVERSITETET I OSLO
DET MEDISINSKE FAKULTET

Forsker dr.scient. Tron Krosshaug
Norges idrettshøgskole
Pb. 4014 Ullevål Stadion
0806 Oslo

Regional komité for medisinsk forskningsetikk
Sør- Norge (REK Sør)
Postboks 1130 Blindern
NO-0318 Oslo
Telefon: 228 44 666
Telefaks: 228 44 661
E-post: rek-2@medisin.uio.no
Nettadresse: www.etikkom.no

Dato: 10.4.07
Deres ref.:
Vår ref.: S-07078a

S-07078a Risikofaktorer for fremre korsbåndskader hos kvinnelige elitehåndballspillere - en prospektiv kohortstudie [2.2007.511]

Vi viser til brev datert 19.3.07 revidert informasjonsskriv med samtykkeerklæring og kopi av brev til klubbene.

Komiteen tar svar på merknader til etterretning.

Komiteen har ingen merknader til revidert informasjonsskriv med samtykkeerklæring.

Komiteen tilrår at prosjektet gjennomføres.

Vi ønsker lykke til med prosjektet.

Med vennlig hilsen

Kristian Hagestad
Fylkeslege cand.med., spes. i samf.med
Leder

Jørgen Hardang
Sekretær

UNIVERSITETET I OSLO

DET MEDISINSKE FAKULTET

Forsker dr.scient. Tron Krosshaug
Norges idrettshøgskole
Pb. 4014 Ullevål Stadion
0806 Oslo

Regional komité for medisinsk og helsefaglig forskningsetikk Sør-Øst A (REK Sør-Øst A)
Postboks 1130 Blindern
NO-0318 Oslo

Telefon: 22 84 46 66
Telefaks: 22 85 05 90
E-post: jorgen.hardang@medisin.uio.no

Dato: 15.12.08
Deres ref.:
Vår ref.: S-07078a

S-07078a Risikofaktorer for fremre korsbåndskader hos kvinnelige elitehåndballspillere - en prospektiv kohortstudie [2.2007.511]

Vi viser til skjema for protokolltillegg og endringer datert 3.12.08 vedlagt revidert informasjonsskriv.

Prosjektleder ønsker å utvide prosjektpopulasjonen til kvinnelige elitefotballspillere fra Toppserien i Norge (ca 240 spillere).

Komiteen godkjenner endringen slik den er beskrevet i skjema for protokolltillegg og endringer og videresender kopi av informasjonsskriv, endringsskjema samt komiteens vedtak til Helsedirektoratet for behandling av endring av biobanken.

Med vennlig hilsen
Kristian Hagestad
Kristian Hagestad
Fylkeslege cand.med., spes. i samf.med
Leder

Jørgen Hardang
Jørgen Hardang
Sekretær

Kopi: Helsedirektoratet, Postboks 7000, St. Olavs plass, 0130 Oslo

Appendix 2

Approval from the Norwegian Social Science Data Services

Norsk samfunnsvitenskapelig datatjeneste AS
NORWEGIAN SOCIAL SCIENCE DATA SERVICES

Harald Hårfagres gate 29
N-5007 Bergen
Norway
Tel: +47-55 58 21 17
Fax: +47-55 58 96 50
nsd@nsd.uib.no
www.nsd.uib.no
Org.nr. 985 321 884

Tron Krosshaug
Senter for idrettsskadeforskning
Norges idrettshøgskole
Pb 4014 Ullevål Stadion
0806 OSLO

Dato: 16.02 2009 | Vår ref: 16639 PB/LR | Deres dato: | Deres ref:

ENDRING AV FORSKNINGSPROSJEKT

Vi viser til endringsmelding mottatt 28.12.2008, samt påfølgende e-postkorrespondanse med daglig ansvarlig (senest 13.02.2009), gjeldende prosjektet

16639 Risikofaktorer for fremre korsbåndskader hos kvinnelige elitehåndball- og elitefotballspillere – en prospektiv kohortstudie

I endringsskjema opplyses det om at man ønsker å utvide prosjektpopulasjonen til å også omfatte kvinnelige elitefotballspillere fra toppserien i Norge (ca. 240 individer). Tittelen på prosjektet endres dermed fra *Risikofaktorer for fremre korsbåndskader hos kvinnelige elitehåndballspillere – en prospektiv kohortstudie* til *Risikofaktorer for fremre korsbåndskader hos kvinnelige elitehåndball- og elitefotballspillere – en prospektiv kohortstudie.*

For hele utvalget ønsker man videre å se på genetiske faktorer som risikofaktorer for fremre korsbåndskader. Man skal ta blodprøve (5 ml. venøs prøve) av deltagerne for å studere genvarianter som kan bidra til å lage et svakere ligament. Kollagen er en viktig substans i ligamenter, og man vil i første omgang se på gener som er ansvarlige for kvaliteten mht. kollagenfibre. Prøven sendes til avidentifisert (med kobling til navneliste som oppbevares ved NIH) til Ullevål Universitetssykehus for å ekstrahere DNA. Ekstrahert DNA vil bli sendt til samarbeidspartner i Sør-Afrika, Exercise Science and Sports Medicine Research Unit (ESSM) for videre analyse. Det vil på grunnlag av analysene gjøres sammenligninger mellom skadede og ikke skadede spillere. Resultatene av testene vil kun være tilgjengelig for dette forskningsformålet. Biobanken opprettes ved Ullevål Universitetssykehus.

En ytterligere endring av prosjektet består i at ombudet etter avtale med daglig ansvarlig Tron Krosshaug, registrerer prosjektet som forskerprosjekt i stedet for som studentprosjekt. Studenten ved NIH Eirik Kristianslund er fortsatt å regne som medarbeider i prosjektet, men registreringsendringen foretas på bakgrunn av at prosjektets tidsperspektiv (planlagt avslutning i 2017) gjør det lite hensiktsmessig å la studenten bli stående som kontaktperson for ombudet. Videre registreres stipendiaten ved NIH Agnethe Nilstad som medarbeider i prosjektet sammen med Dr. Scient. Kathrin Steffen og Dr. Med. Thor Einar Andersen.

Ombudet mottok 13.02.2009 reviderte informasjonsskriv for rekruttering av deltagere til prosjektet og finner begge skrivene meget tilfredsstillende.

Ombudet legger til grunn at endringen, inkludert opprettelsen av forskningsbiobank, godkjennes av REK. Det bes om at kopi av tilråding ettersendes.

Ombudet anbefaler at det opprettes en databehandleravtale med Ullevål og med ESSM, jf. personopplysningsloven § 15.

Endringene medfører ingen endring av ombudets opprinnelige vurdering og tilråding av prosjektet (se brev datert 03.05.2007) mht. behandlings- eller hjemmelsgrunnlag.

Ombudet minner om at bruk av videoopptak i undervisnings- eller formidlingsøyemed kan medføre meldeplikt overfor Datatilsynet. Dette bør avklares direkte med tilsynet.

Ta gjerne kontakt dersom noe er uklart.

Vennlig hilsen

Bjørn Henrichsen

Pernilla Bollman

Kontaktperson: Pernilla Bollman 55 58 24 10

Appendix 3

Informational letter from the Norwegian Football Federation to the elite female football league

Norges Fotballforbund
The Football Association of Norway
NO-0840 Oslo, Norway
Telefon: 04420, Fax: +47 21 02 93 01
International calls: +47 21 02 93 00
www.fotball.no

Klubbene i Toppserien 2009
v/leder og sportslig ledelse

Oslo, 16. desember 2008

Forskningsprosjekt – risikoen for korsbåndskader

Norges Fotballforbund har fått en henvendelse fra *Senter for idrettsskadeforskning* ved Norges idrettshøgskole i Oslo som ønsker å gjennomføre en kartleggingsprosess av samtlige spillere i Toppserien 2009. Formålet med arbeidet er å få detaljert kunnskap om hva som forårsaker de mange korsbåndsskadene blant våre kvinnelige fotballspillere, slik at vi kan forebygge disse skadene så effektivt som mulig til det beste for den enkelte spiller, for spillerens klubb og for norsk kvinnefotball i sin helhet.

Senter for idrettsskadeforskning ønsker å gjennomføre kartleggingen i løpet av januar og februar 2009 og registrere alle skader i 2009 sesongen. Spillerne vil bli fulgt de neste fire årene for å registrere korsbåndskadene til denne gruppen (se vedlegg for mer informasjon).

Dette kartleggingsarbeidet mener vi i Norges Fotballforbund er viktig! Ved å teste et så stort antall spillere, er det lettere å finne årsaker til at korsbåndskadene oppstår. Dermed kan vi lettere iverksette til riktige tiltakene på både klubb-, regions- og landslagsnivå for å forbygge akkurat disse skadene.

Vi håper derfor at dette tilbudet er interessant for din klubb. I praksis betyr det at spillerne blir invitert inn til en dag med testing på Norges Idrettshøgskole i Oslo. Resultatet av testen sier også noe om spillernes fysiske prestasjonsevne, informasjon som er verdifull for klubbens trenere i evaluering og planlegging av treningene. Alle utgifter i forbindelse med testdagen vil bli dekket av *Senter for idrettsskadeforskning*.

Norges Fotballforbund vil kontakte klubbene i Toppserien i primo januar 2009, for å avklare om din klubb ønsker å være med å dette. Da avklarer vi også testdag og bistår i administrering / logistikk i forbindelse med testingen på Norges Idrettshøgskole.

Med hilsen
NORGES FOTBALLFORBUND

Per-Mathias Høgmo
Toppfotballsjef

Jarl Torske
Trener U-19/20
Ansv. sport Jenteløftet

Heidi Støre
Leder Toppfotball kvinner

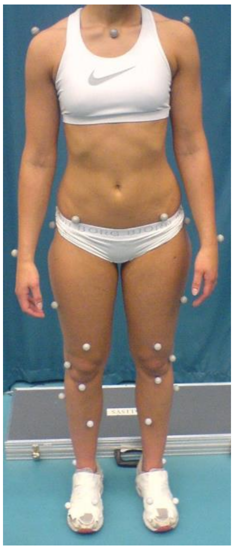
Appendix 4

Test information to all clubs in the female elite league

Forskningsprosjekt blant fotballspillere i Toppserien 2009

Senter for idrettsskadeforskning ved Norges idrettshøgskole gjennomfører et forskningsprosjekt der vi undersøker risikofaktorer for korsbåndskader blant kvinnelige elitefotballspillere. Vi testet hele eliteserien i håndball for kvinner i løpet av juni 2007, og tilsvarende testing skal nå gjennomføres blant kvinnelige fotballspillere i Toppserien i februar og mars 2009. Spillerne følges deretter opp de kommende sesongene i form av å registrere eventuelle korsbåndskader som oppstår.

Vi har satt av tid til testing av spillere fra **Kolbotn tirsdag 24.februar kl.0900.** Testingen foregår på Norges idrettshøgskole, og dere kan møte opp i resepsjonen ved hovedinngangen. Vi vil da ha et kort informasjonsmøte først, hvor vi også ber alle om å skrive under på en samtykkeerklæring for prosjektdeltakelsen.



Vi har totalt 7 teststasjoner som innebærer 3D bevegelsesanalyse av finter/vendinger og fallhopp/spenst, styrketester av forside/bakside lår og hofte, bevegelighet, balansetester, anatomiske målinger og en blodprøve. Testingen vil totalt ta ca.7 timer, og dere vil selvfølgelig få pause, samt mat og drikke underveis.

Under testingen har dere på treningstøy og de skoene dere vanligvis bruker til innetrening. For å gjøre testingen lettere bør dere bruke en shorts og t-skjorte. To av testene krever at hofter/hoftekam er tilgjengelig for markører (se bilde), så ta gjerne på en boksershorts eller eventuelt en kort sykkelshorts til disse testene. Markørene vi bruker til bevegelsesanalysen festes med teip – **unngå derfor å bruke bodylotion** på testdagen.

For å se bilder fra testingen kan dere finne dette på hjemmesiden til Senter for idrettsskadeforskning; http://www.klokeavskade.no/no/Nyhetsarkiv/Nyhetsarkiv-2007/Ny-studie-i-kvinnenes-eliteserie-i-handball/

Dersom dere har spørsmål kan dere ta kontakt på telefon (99 22 44 69) eller e-post (agnethe.nilstad@nih.no).

Vi ser frem til å møte dere!

Vennlig hilsen

Agnethe Nilstad
Fysioterapeut MSc, PhD-kandidat
Senter for idrettsskadeforskning

Appendix 5

Informed consent

FORESPØRSEL OM DELTAKELSE I PROSJEKTET:
"Risikofaktorer for fremre korsbåndskader hos kvinnelige elitehåndball- og fotballspillere - En prospektiv kohortstudie"

Bakgrunn for undersøkelsen
Korsbåndsskader i fotball og håndball har i det siste vært et svært aktuelt tema, både i media og i forskningssammenheng. Dette skyldes først og fremst den relativt store hyppigheten av denne alvorlige skaden, spesielt blant kvinnelige utøvere, som ser ut til å skade seg 3-7 ganger hyppigere enn menn. Problemet så langt er imidlertid at vi vet for lite om risikofaktorene og skademekanismene for korsbåndskader. Denne informasjonen er viktig når vi forsøker å forebygge skader, både for å kunne vite hvem som vil ha størst glede av forebyggende trening og for å kunne utvikle mest mulig effektive treningsmetoder.

Senter for idrettsskadeforskning er en forskningsgruppe bestående av fysioterapeuter, kirurger og biomekanikere med kunnskap innen idrettsmedisin. Vår hovedmålsetting er å forebygge skader i norsk idrett, med spesiell satsning på fotball, håndball, ski og snowboard. Denne studien er en viktig brikke i arbeidet med å finne ut hvorfor noen får en korsbåndskade. Vi ønsker nå å undersøke ulike mulige risikofaktorer for korsbåndskader, for deretter å kartlegge hvem som får korsbåndskader de påfølgende sesongene.

Gjennomføring av undersøkelsen
Vi ønsker at du som elitespiller deltar i denne studien, og deltakelsen er frivillig. Testingen vil finne sted på Norges idrettshøgskole. I løpet av en dag vil vi gjennomføre ulike styrke-, balanse- og bevegelighetstester, anatomiske målinger, samt gjennomføre en bevegelsesanalyse av hvordan du finter, vender, hopper og lander. Undersøkelsen starter med en kort oppvarming, deretter får du festet små refleksmarkører på kroppen (35 stk totalt). Du vil så bli bedt om å gjennomføre tre finter/vendinger og tre fallhopp. Under disse øvelsene vil det være 8 infrarøde kamera som filmer markørene, samtidig som kreftene fra underlaget blir målt. Dataene fra markører, kraftplattform og anatomiske mål benyttes i en matematisk modell som gir ut leddkrefter og momenter. Disse kreftene/momentene gir oss informasjon om hvordan muskler og passive strukturer som leddbånd belastes.

Bevegelsesanalysen vil ta ca. 1,5 time, inkludert anatomiske målinger og påsetting av markører. De andre testene gjennomføres resten av tiden laget er på NIH, og totalt vil testene ta om lag åtte timer. I tillegg til disse testene vil du få utdelt et skjema, der vi spør om treningserfaring, tidligere skader, skade i familien, treningsmengde, menstruasjonsstatus og knefunksjon. Spørreskjemaet besvares i løpet av testdagen, og det vil ta ca. 30 min.

Behandling av testresultatene
Vi vil de neste tre sesongene følge opp alle lag og spillere som har deltatt på testing hos oss for å registrere alle korsbåndskader som oppstår.

Vi er også interessert i å kunne kontakte deg senere med tanke på oppfølgningsstudier. Dette kan f.eks. skje ved at du får tilsendt et spørreskjema. Av den grunn vil vi lagre resultatene fra testene og svarene på spørreskjemaet fram til 1.6.2017. Etter dette vil dataene bli anonymisert. Dataene vil bli behandlet konfidensielt, og kun i forskningsøyemed. Alle som utfører testingen og forskere som benytter dataene er underlagt taushetsplikt. Dersom du ikke ønsker å være med på etterundersøkelser, kan du reservere deg mot dette i samtykkeerklæringen. I så fall vil alle dine data bli anonymisert etter fire år.

Vi vil underveis i testingen ta videoopptak av dere som vi senere kan ønske å bruke i undervisnings- og formidlingssammenheng. Opptakene inkluderer situasjoner der dere kun har på shorts og sports-BH. Dersom dere ikke vil at deres opptak skal være aktuelle for slik bruk krysser dere av for det i samtykkeerklæringen.

Hva får du ut av det?
Vi kan ikke tilby noe honorar for oppmøtet, men vil dekke eventuelle reise- og matutgifter. I tillegg vil du få kopi av dine resultater fra styrketestene som gjennomføres i løpet av testdagen.

Angrer du?
Du kan selvfølgelig trekke deg fra forsøket når som helst uten å måtte oppgi noen grunn. Alle data som angår deg vil uansett bli anonymisert.

Spørsmål?
Ring gjerne til Tron Krosshaug, tlf.: 45 66 00 46 hvis du har spørsmål om prosjektet, eller send e-post til tron.krosshaug@nih.no.

"Risikofaktorer for fremre korsbåndskader hos kvinnelige elitehåndball- og fotballspillere - En prospektiv kohortstudie"

SAMTYKKEERKLÆRING

Jeg har mottatt skriftlig og muntlig informasjon om studien *Risikofaktorer for fremre korsbåndskader hos kvinnelige elitehåndball- og fotballspillere - En prospektiv kohortstudie*. Jeg er klar over at jeg kan trekke meg fra undersøkelsen på et hvilket som helst tidspunkt.

☐ Jeg ønsker ikke å bli kontaktet etter endt karriere med tanke på oppfølgningsstudier
☐ Jeg ønsker ikke at video av meg skal brukes i undervisningssammenheng

Sted ……………………….. Dato ………………………..

....
Underskrift

....
Navn med blokkbokstaver

....
Adresse

....
Mobiltelefon

....
E-postadresse

Appendix 6

Questionnaire from the screening test battery

499

Fotballprosjekt

2009 - 2012

SENTER FOR
Idrettsskadeforskning

www.klokeavskade.no

499

Navn

☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐

Personnummer (11 siffer)

☐☐☐☐☐☐☐☐☐☐☐

Lag

☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐

Spillerposisjon

☐ Målvakt ☐ Bakspiller ☐ Midtbane
☐ Ving
☐ Spiss

Dominant arm

☐ Høyre ☐ Venstre

Dominant ben
(Hvilket ben foretrekker du å sparke en ball med?)

☐ Høyre ☐ Venstre

Høyde ☐☐☐ cm **Vekt** ☐☐☐ kg

Medikasjon: Har du brukt smertestillende den siste uken? ☐ Ja ☐ Nei

Tidligere skader

Hvor mange tidligere ankelovertråkk har du hatt det siste året? Høyre ☐☐ Venstre ☐☐

Har du skadet ett eller flere fremre korsbånd?

Nei ☐ Høyre ☐ Venstre ☐ Begge ☐

Hvis JA, vennligst fyll ut A-H:

OBS!
Hvis du har hatt flere korsbåndskader, vennligst ta kontakt med en av oss på teststasjonene.

A: Når? (DDMMÅÅ) ☐☐☐☐☐☐

B: Ble du operert? ☐ Ja ☐ Nei

C: Skjedde skaden på trening og/eller i kamp? I kamp ☐ På trening ☐ I kamp og på trening ☐

D: Skjedde skaden ved direkte støt mot kneet? ☐ Ja ☐ Nei ☐ Husker ikke

E: Hva slags bevegelse gjorde du da skaden skjedde?

☐ Finte ☐ Ettbens landing ☐ Tobens landing ☐ Vending ☐ Annet (skriv)

Annet? Hva (beskriv): ____________________

F: Gikk kampen på TV? ☐ Ja ☐ Nei ☐ Husker ikke

G: Kjenner du til noe annet videoopptak av skaden? ☐ Ja ☐ Nei

H: Brukte du p-piller på den tiden? ☐ Ja ☐ Nei ☐ Husker ikke

[redacted]

499

Familie

Har du søsken eller foreldre som har skadet korsbåndet?

☐ Ja ☐ Nei ☐ Vet ikke

Forebygging

Har du deltatt i noe program for å forebygge korsbåndskader?

Deltar nå: ☐ Ja ☐ Nei

Har deltatt før: ☐ Ja ☐ Nei

Hvis du deltar i forebyggende program, hva går dette ut på?

Balansetrening: ☐ Ja ☐ Nei

Styrketrening: ☐ Ja ☐ Nei

Teknikk/hopptrening: ☐ Ja ☐ Nei

Hvor ofte gjør du slike øvelser?

☐ < 1 gang i uken ☐ 1-2 ganger i uken ☐ 3-4 ganger i uken ☐ > 4 ganger i uken

Når gjør dere dette programmet? ☐ Hele året ☐ I oppkjøringen ☐ I sesongen

Trening/kamp/erfaring

Hvor mange **timer** i uken (hele timer) trener du totalt **i sesongen** med:

Fotball ☐☐ Styrke ☐☐ Utholdenhet ☐☐ Annet ☐☐

Annet? Hva (beskriv): ____________________

Hvor mange **timer** i uken (hele timer) trener du **nå** med:

Fotball ☐☐ Styrke ☐☐ Utholdenhet ☐☐ Annet ☐☐

Annet? Hva (beskriv): ____________________

Hvor mange **timer** (gjennomsnitt, hele timer) i uken spiller du kamp? ☐☐ timer

Hvor gammel var du når du begynte å spille fotballpå elitenivå? ☐☐ år

Hvor mange sesonger har du spilt fotball på elitenivå? ☐☐ sesonger

Menstruasjon

Hvor mange menstruasjonsblødninger har du hatt de siste 12 månedene? ☐☐

Hvor mange dager går det fra første dags blødning til neste blødning? (vanlig 28-36 dager) ☐☐

Bruker du p-piller nå? ☐ Ja ☐ Nei

Hvis ja, hvor mange år har du brukt p-piller? ☐☐

Hvilken merke p-piller bruker du? Hvilken type p-pille?

Skriv ____________________

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Opplysninger om tidligere kneskader, også korsbåndskader

Venstre kne

Antall tidligere akutte skader (også korsbåndskade)
☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ >5

Om du svarte "0" på dette spørsmålet, hopp over resten av kolonnen og gå rett til høyre kne.

Tid siden siste skade:
☐ 0-6 mnd ☐ 6-12 mnd ☐ 1-2 år ☐ >2 år

Hvor lenge har du vært ute fra kamp/full trening?
☐ 1-3 dager ☐ 4-7 dager ☐ 1-4 uker ☐ >4 uker

Bruker du vanligvis noen form for knebeskyttelse?
☐ Ja ☐ Nei

Hvis JA, hvilken?

Tape	☐ Av og til	☐ Alltid
Kneskinne/ ortose	☐ Av og til	☐ Alltid

Hvis du har en tidligere kneskade, hva slags skade var det?

Har du skadet menisk?
☐ Innside ☐ Utside ☐ Begge sider ☐ Vet ikke

Har du skadet leddbånd?
☐ Innside ☐ Utside ☐ Begge sider ☐ Vet ikke

Har du skadet korsbånd?
☐ Fremre (ACL) ☐ Bakre (PCL) ☐ Begge
☐ Vet ikke

Har du tidligere bruskskade i kneet?
☐ Innside ☐ Utside ☐ Begge sider ☐ Vet ikke

Har du tidligere brudd i nærheten av kneet?

Kneskålen	☐ Nei	☐ Ja	☐ Vet ikke
Lårbenet	☐ Nei	☐ Ja	☐ Vet ikke
Skinnbenet	☐ Nei	☐ Ja	☐ Vet ikke
Leggbenet	☐ Nei	☐ Ja	☐ Vet ikke

Høyre kne

Antall tidligere akutte skader (også korsbåndskade)
☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ >5

Om du svarte "0" på dette spørsmålet, hopp over resten av kolonnen og gå rett til neste del.

Tid siden siste skade:
☐ 0-6 mnd ☐ 6-12 mnd ☐ 1-2 år ☐ >2 år

Hvor lenge har du vært ute fra kamp/full trening?
☐ 1-3 dager ☐ 4-7 dager ☐ 1-4 uker ☐ >4 uker

Bruker du vanligvis noen form for knebeskyttelse?
☐ Ja ☐ Nei

Hvis JA, hvilken?

Tape	☐ Av og til	☐ Alltid
Kneskinne/ ortose	☐ av og til	☐ alltid

Hvis du har en tidligere kneskade, hva slags skade var det?

Har du skadet menisk?
☐ Innside ☐ Utside ☐ Begge sider ☐ Vet ikke

Har du skadet leddbånd?
☐ Innside ☐ Utside ☐ Begge sider ☐ Vet ikke

Har du skadet korsbånd?
☐ Fremre (ACL) ☐ Bakre (PCL) ☐ Begge
☐ Vet ikke

Har du tidligere bruskskade i kneet?
☐ Innside ☐ Utside ☐ Begge sider ☐ Vet ikke

Har du tidligere brudd i nærheten av kneet?

Kneskålen	☐ Nei	☐ Ja	☐ Vet ikke
Lårbenet	☐ Nei	☐ Ja	☐ Vet ikke
Skinnbenet	☐ Nei	☐ Ja	☐ Vet ikke
Leggbenet	☐ Nei	☐ Ja	☐ Vet ikke

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Knefunksjon

Instruksjoner: Denne delen av spørreskjemaet inneholder spørsmål om hvordan du opplever ditt kne. Informasjonen vil hjelpe oss å følge med på hvordan du fungerer på trening, i kamp og i det daglige liv. Besvar spørsmålene ved å krysse av for det alternativet du synes stemmer best med deg (kun ett kryss ved hvert spørsmål). Om du er usikker, kryss likevel for det alternativet du synes beskriver situasjonen best. Husk å svare for både høyre og venstre kne.

Symptomer

Tenk over symptomene du har hatt fra kneet ditt **den siste uken** når du besvarer disse spørsmålene.

KS1. Har kneet vært hovent?

Venstre kne					Høyre kne				
Aldri	Sjelden	Iblant	Ofte	Alltid	Aldri	Sjelden	Iblant	Ofte	Alltid
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

KS2. Har du følt knirking, hørt klikking eller andre lyder fra kneet?

Venstre kne					Høyre kne				
Aldri	Sjelden	Iblant	Ofte	Alltid	Aldri	Sjelden	Iblant	Ofte	Alltid
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

KS3. Har kneet haket seg opp eller låst seg?

Venstre kne					Høyre kne				
Aldri	Sjelden	Iblant	Ofte	Alltid	Aldri	Sjelden	Iblant	Ofte	Alltid
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

KS4. Har du kunne rette kneet helt ut?

Venstre kne					Høyre kne				
Alltid	Ofte	Iblant	Sjelden	Aldri	Alltid	Ofte	Iblant	Sjelden	Aldri
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

KS5. Har du kunne bøye kneet helt?

Venstre kne					Høyre kne				
Alltid	Ofte	Iblant	Sjelden	Aldri	Alltid	Ofte	Iblant	Sjelden	Aldri
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Stivhet

De neste spørsmålene handler om. Leddstivhet innebærer vanskeligheter med å komme i gang eller økt motstand når du bøyer eller strekker kneet. Marker graden av leddstivhet du har opplevd i kneet **den siste uken**.

KS6. Hvor stivt er kneet ditt når du nettopp har våknet om morgenen?

Venstre kne					Høyre kne				
Ikke noe	Litt	Moderat	Betydelig	Extremt	Ikke noe	Litt	Moderat	Betydelig	Extremt
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

KS7. Hvor stiv er kneet ditt senere på dagen etter å ha sittet, ligget eller hvilt?

Venstre kne					Høyre kne				
Ikke noe	Litt	Moderat	Betydelig	Extremt	Ikke noe	Litt	Moderat	Betydelig	Extremt
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

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Smerte

KP1. Hvor ofte har du vondt i kneet?

Venstre kne					Høyre kne				
Aldri	Månedlig	Ukentlig	Daglig	Hele tiden	Aldri	Månedlig	Ukentlig	Daglig	Hele tiden
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Hvor sterke smerter har du hatt i kneet ditt <u>den siste uken</u> ved følgende aktiviteter.

KP2. Snu/vende på belastet kne

Venstre kne					Høyre kne				
Ingen	Lette	Moderate	Betydelige	Svært store	Ingen	Lette	Moderate	Betydelige	Svært store
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

KP3. Rette kneet helt ut

Venstre kne					Høyre kne				
Ingen	Lette	Moderate	Betydelige	Svært store	Ingen	Lette	Moderate	Betydelige	Svært store
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

KP4. Bøye kneet helt

Venstre kne					Høyre kne				
Ingen	Lette	Moderate	Betydelige	Svært store	Ingen	Lette	Moderate	Betydelige	Svært store
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

KP5. Gå på flatt underlag

Venstre kne					Høyre kne				
Ingen	Lette	Moderate	Betydelige	Svært store	Ingen	Lette	Moderate	Betydelige	Svært store
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

KP6. Gå opp eller ned trapper

Venstre kne					Høyre kne				
Ingen	Lette	Moderate	Betydelige	Svært store	Ingen	Lette	Moderate	Betydelige	Svært store
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

KP7. Om natten (smerter som forstyrrer søvnen)

Venstre kne					Høyre kne				
Ingen	Lette	Moderate	Betydelige	Svært store	Ingen	Lette	Moderate	Betydelige	Svært store
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

KP8. Sittende eller liggende

Venstre kne					Høyre kne				
Ingen	Lette	Moderate	Betydelige	Svært store	Ingen	Lette	Moderate	Betydelige	Svært store
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

KP9. Stående

Venstre kne					Høyre kne				
Ingen	Lette	Moderate	Betydelige	Svært store	Ingen	Lette	Moderate	Betydelige	Svært store
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

[redacted]

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Funksjon i hverdagen

Følgende spørsmål handler om din fysiske funksjon. Angi graden av vanskeligheter du har opplevd **den siste uken** ved følgende aktiviteter på grunn av dine kneproblemer.

KA1. Gå ned trapper

	Ingen	Lette	Moderate	Betydelige	Svært store
Venstre kne	☐	☐	☐	☐	☐
Høyre kne	☐	☐	☐	☐	☐

KA2. Gå opp trapper

	Ingen	Lette	Moderate	Betydelige	Svært store
Venstre kne	☐	☐	☐	☐	☐
Høyre kne	☐	☐	☐	☐	☐

KA3. Reise deg fra sittende stilling

	Ingen	Lette	Moderate	Betydelige	Svært store
Venstre kne	☐	☐	☐	☐	☐
Høyre kne	☐	☐	☐	☐	☐

KA4. Stå stille

	Ingen	Lette	Moderate	Betydelige	Svært store
Venstre kne	☐	☐	☐	☐	☐
Høyre kne	☐	☐	☐	☐	☐

KA5. Bøye deg, f.eks. for å plukke opp en gjenstand fra gulvet

	Ingen	Lette	Moderate	Betydelige	Svært store
Venstre kne	☐	☐	☐	☐	☐
Høyre kne	☐	☐	☐	☐	☐

KA6. Gå på flatt underlag

	Ingen	Lette	Moderate	Betydelige	Svært store
Venstre kne	☐	☐	☐	☐	☐
Høyre kne	☐	☐	☐	☐	☐

KA7. Gå inn i/ut av bil

	Ingen	Lette	Moderate	Betydelige	Svært store
Venstre kne	☐	☐	☐	☐	☐
Høyre kne	☐	☐	☐	☐	☐

KA8. Handle/gjøre innkjøp

	Ingen	Lette	Moderate	Betydelige	Svært store
Venstre kne	☐	☐	☐	☐	☐
Høyre kne	☐	☐	☐	☐	☐

KA9. Ta på sokker/strømper

	Ingen	Lette	Moderate	Betydelige	Svært store
Venstre	☐	☐	☐	☐	☐
Høyre kne	☐	☐	☐	☐	☐

KA10. Stå opp fra sengen

	Ingen	Lette	Moderate	Betydelige	Svært store
Venstre kne	☐	☐	☐	☐	☐
Høyre kne	☐	☐	☐	☐	☐

KA11. Ta av sokker/strømper

Venstre kne					Høyre kne				
Ingen	Lette	Moderate	Betydelige	Svært store	Ingen	Lette	Moderate	Betydelige	Svært store
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

KA12. Ligge i sengen (snu deg, holde kneet i samme stilling i lengre tid)

Venstre kne					Høyre kne				
Ingen	Lette	Moderate	Betydelige	Svært store	Ingen	Lette	Moderate	Betydelige	Svært store
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

KA13. Gå inn i/ut av badekar/dusj

Venstre kne					Høyre kne				
Ingen	Lette	Moderate	Betydelige	Svært store	Ingen	Lette	Moderate	Betydelige	Svært store
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

KA14. Sitte

Venstre kne					Høyre kne				
Ingen	Lette	Moderate	Betydelige	Svært store	Ingen	Lette	Moderate	Betydelige	Svært store
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

KA15. Sette deg på og reise deg fra toalettet

Venstre kne					Høyre kne				
Ingen	Lette	Moderate	Betydelige	Svært store	Ingen	Lette	Moderate	Betydelige	Svært store
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

KA16. Gjøre tungt husarbeide (måke snø, vaske gulv, støvsuge osv.)

Venstre kne					Høyre kne				
Ingen	Lette	Moderate	Betydelige	Svært store	Ingen	Lette	Moderate	Betydelige	Svært store
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

KA17. Gjøre lett husarbeide (lage mat, tørke støv osv.)

Venstre					Høyre kne				
Ingen	Lette	Moderate	Betydelige	Svært store	Ingen	Lette	Moderate	Betydelige	Svært store
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Funksjon i sport og fritid

Følgende spørsmål handler om din fysiske funksjon. Angi grad av vanskelighet du har opplevd **<u>den siste uken</u>** ved følgende aktiviteter på grunn av dine kneproblemer.

KSP1. Sitte på huk

Venstre kne					Høyre kne				
Ingen	Lette	Moderate	Betydelige	Svært store	Ingen	Lette	Moderate	Betydelige	Svært store
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

KSP2. Løpe

Venstre kne					Høyre kne				
Ingen	Lette	Moderate	Betydelige	Svært store	Ingen	Lette	Moderate	Betydelige	Svært store
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

KSP3. Hoppe

Venstre kne					Høyre kne				
Ingen	Lette	Moderate	Betydelige	Svært store	Ingen	Lette	Moderate	Betydelige	Svært store
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

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KSP4. Snu/vende på belastet kne

Venstre kne

Ingen	Lette	Moderate	Betydelige	Svært store
☐	☐	☐	☐	☐

Høyre kne

Ingen	Lette	Moderate	Betydelige	Svært store
☐	☐	☐	☐	☐

KSP5. Stå på kne

Venstre kne

Ingen	Lette	Moderate	Betydelige	Svært store
☐	☐	☐	☐	☐

Høyre kne

Ingen	Lette	Moderate	Betydelige	Svært store
☐	☐	☐	☐	☐

Livskvalitet

Følgende spørsmål angår hvordan dine problemer i kneet hemmer deg slik at du ikke kan gi maksimalt du kan når du utøver din fysiske aktivitet.

KQ1. Hvor ofte gjør ditt kneproblem seg bemerket?

Venstre kne

Aldri	Månedlig	Ukentlig	Daglig	Hele tiden
☐	☐	☐	☐	☐

Høyre kne

Aldri	Månedlig	Ukentlig	Daglig	Hele tiden
☐	☐	☐	☐	☐

KQ2. Har du forandret levesett for å unngå å overbelaste kneet?

Venstre kne

Ingenting	Noe	Moderat	Betydelig	Fullstendig
☐	☐	☐	☐	☐

Høyre kne

Ingenting	Noe	Moderat	Betydelig	Fullstendig
☐	☐	☐	☐	☐

KQ3. I hvor stor grad kan du stole på kneet ditt?

Venstre kne

Ikke	Noe	Moderat	I stor grad	Fullstendig
☐	☐	☐	☐	☐

Høyre kne

Ikke	Noe	Moderat	I stor grad	Fullstendig
☐	☐	☐	☐	☐

KQ4. Generelt sett, hvor store problemer har du med kneet ditt?

Venstre kne

Ingen	Lette	Moderate	Betydelige	Svært store
☐	☐	☐	☐	☐

Høyre kne

Ingen	Lette	Moderate	Betydelige	Svært store
☐	☐	☐	☐	☐

Opplysninger om tidligere ankelskader

HØYRE ANKEL	VENSTRE ANKEL
Antall tidligere akutte skader (overtråkk): ☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ >5 Om du svarte "0" på dette spørsmålet, hopp over de neste 3 spørsmålene om høyre ankel.	Antall tidligere akutte skader (overtråkk): ☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ >5 Om du svarte "0" på dette spørsmålet, hopp over de neste 3 spørsmålene om venstre ankel.
Tid siden siste skade: ☐ 0-6 mnd ☐ 6-12 mnd ☐ 1-2 år ☐ >2 år	Tid siden siste skade: ☐ 0-6 mnd ☐ 6-12 mnd ☐ 1-2 år ☐ >2 år
Hvor lenge var du ute fra kamp / full trening? ☐ 1-3 dager ☐ 4-7 dager ☐ 1-4 uker ☐ >4 uker	Hvor lenge var du ute fra kamp / full trening? ☐ 1-3 dager ☐ 4-7 dager ☐ 1-4 uker ☐ >4 uker
Bruker du vanligvis noen form for ankelbeskyttelse? ☐ Nei ☐ Tape ☐ Alltid ☐ Av og til ☐ Ankelstøtte ☐ Alltid ☐ Av og til	Bruker du vanligvis noen form for ankelbeskyttelse? ☐ Nei ☐ Tape ☐ Alltid ☐ Av og til ☐ Ankelstøtte ☐ Alltid ☐ Av og til

Opplysninger om strekkskader på baksiden av låret

HØYRE LåR	VENSTRE LÅR
Antall tidligere akutte skader bakside lår (strekk): ☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ >5 Om du svarte "0" på dette spørsmålet, hopp over de neste 3 spørsmålene om høyre lår.	Antall tidligere akutte skader bakside lår (strekk): ☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ >5 Om du svarte "0" på dette spørsmålet, hopp over de neste 3 spørsmålene om venstre lår.
Tid siden siste skade: ☐ 0-6 mnd ☐ 6-12 mnd ☐ 1-2 år ☐ >2 år	Tid siden siste skade: ☐ 0-6 mnd ☐ 6-12 mnd ☐ 1-2 år ☐ >2 år
Hvor lenge var du ute fra kamp / full trening?: ☐ 1-3 dager ☐ 4-7 dager ☐ 1-4 uker ☐ >4 uker	Hvor lenge var du ute fra kamp / full trening?: ☐ 1-3 dager ☐ 4-7 dager ☐ 1-4 uker ☐ >4 uker
Har du stått over trening / kamp siste sesong pga problemer på baksiden av låret? ☐ Aldri ☐ Ja ☐ Sjelden ☐ Av og til ☐ Ofte	Har du stått over trening / kamp siste sesong pga problemer på baksiden av låret? ☐ Aldri ☐ Ja ☐ Sjelden ☐ Av og til ☐ Ofte

Opplysninger om strekkskader i lysken

HØYRE LYSKE	VENSTRE LYSKE
Antall tidligere akutte skader (strekk, lyskebrokk): ☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ >5 Om du svarte "0" på dette spørsmålet, hopp over de neste 4 spørsmålene.	Antall tidligere akutte skader (strekk, lyskebrokk): ☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ >5 Om du svarte "0" på dette spørsmålet, hopp over de neste 4 spørsmålene.
Tid siden siste skade: ☐ 0-6 mnd ☐ 6-12 mnd ☐ 1-2 år ☐ >2 år	Tid siden siste skade: ☐ 0-6 mnd ☐ 6-12 mnd ☐ 1-2 år ☐ >2 år
Hvor lenge var du ute fra kamp / full trening?: ☐ 1-3 dager ☐ 4-7 dager ☐ 1-4 uker ☐ >4 uker	Hvor lenge var du ute fra kamp / full trening?: ☐ 1-3 dager ☐ 4-7 dager ☐ 1-3 uker ☐ >4 uker
Behandling ved siste skade: ☐ operasjon ☐ fysioterapi ☐ ingen ☐ vet ikke	Behandling ved siste skade: ☐ operasjon ☐ fysioterapi ☐ ingen ☐ vet ikke
Er du operert for "lyskebrokk? ☐ Nei ☐ Ja	Er du operert for "lyskebrokk? ☐ Nei ☐ Ja

SPØRRESKJEMA OM SMERTER I KORSRYGGEN

Anvisning for besvarelse av spørreskjemaet:

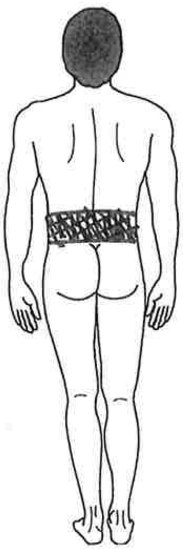
- Med korsrygg menes den skraverte delen av figuren, altså den nedre delen av ryggen.

- Med smerter i korsryggen menes smerter, verk eller ubehag i korsryggen med eller uten utstråling til ett eller begge bein (isjias).

- Vi ønsker at du skal besvare spørreskjemaet selv om du ikke har hatt noen problemer med smerter i korsryggen.

- Smerter i korsryggen forårsaket av menstruasjon skal ikke føres inn i skjemaet.

- Svar ved å sette et kryss i ruten for det nærmeste svaralternativet. NB! Sett bare ett kryss for hvert spørsmål hvis ikke annet er angitt. Om du ikke er helt sikker på hva du skal svare, så forsøk likevel å svare så godt du kan.



A. PERSONOPPLYSNINGER

1. Hvor mange timer totalt har du trent de siste 12 månedene?

1 [ ] Mindre enn 400 timer
2 [ ] 400-549 timer
3 [ ] 550-699 timer
4 [ ] Mer enn 700 timer

2. Har du noen gang hatt problemer med korsryggen, smerter, verk eller ubehag?

1 [ ] Nei
2 [ ] Ja

Om du svarer nei på spørsmål 2 skal du ikke svare på spørsmål 3 -15

3. Fører smertene i korsryggen til søvnproblemer?

1 [ ] Ja
2 [ ] Nei

4. Har du noen gang på grunn av smerter i korsryggen måttet bytte arbeid eller arbeidsoppgaver?

1 [ ] Nei
2 [ ] Ja

5. Har du hatt smerter i korsryggen i løpet av de siste 7 dagene?

1 [ ] Nei
2 [ ] Ja

6. Hvor mange dager har du hatt smerter i korsryggen de siste 12 månedene?

1 [ ] 0 dager
2 [ ] 1 - 7 dager
3 [ ] 8 - 30 dager
4 [ ] Mer enn 30 dager, men ikke daglig
5 [ ] Daglig

7. Har du på grunn av smerter i korsryggen blitt underøkt eller behandlet av lege, fysioterapeut, kiropraktor eller annet helsepersonell utenom sykehus de siste 12 månedene?

1 Nei
2 Ja

8. Har du noen gang på grunn av smerter i korsryggen gjennomgått en operasjon?

1 Nei
2 Ja

9. Har du noen gang hatt smerter fra korsryggen som stråler ut i beina?

1 Nei
2 Ja, ut i setet
3 Ja, ut til låret
4 Ja, ut til kneet
5 Ja, ut til leggen eller foten

10. I hvilken forbindelse har du opplevd smerter i korsryggen?

1 Akutt smerte som resultat av skade
2 Smerte over tid som resultat av overbelastning
3 Begge deler

11. Hvor mange dager har du måttet stå over trening på grunn av smerter i korsryggen i løpet av de siste 12 månedene?

1 0 dager
2 1 - 7 dager
3 8 - 30 dager
5 Mer enn 30 dager

12. Hvor mange kamper har du måttet stå over på grunn av smerter i korsryggen de siste 12 månedene?

1 Ingen
2 1 - 3 kamper
3 4 - 10 kamper
4 Mer enn 10 kamper

13. Har du hatt smerter i korsryggen i følgende deler av det siste treningsåret (treningsperioder):

13.1. Aktiv avkoplingsperiode?

1 Nei 2 Av og til 3 Ukentlig 4 Daglig

13.2. Oppkjøringsperiode?

1 Nei 2 Av og til 3 Ukentlig 4 Daglig

13.3. Midt i sesongen?

1 Nei 2 Av og til 3 Ukentlig 4 Daglig

14. Har smerter i korsryggen vært forårsaket av kontakt med annen spiller?

1 Nei
2 Ja

15. Om du har opplevd smerter i korsryggen i spillsituasjoner, hvilke?
NB! Her kan du sette flere kryss.

1 Ved skudd
2 Ved maks løp
3 Ved pasningsspill
4 Ved vending/finte
5 Landing
6 Takling
7 Blokkering av skudd
8 Annet: Hva?

Appendix 7

Training and match exposure form

KLUBBSKJEMA: KAMP & TRENINGSREGISTRERING

Klubb:	Måned: April 2009

Dato	*Aktivitet*	*Antall spillere*	*Varighet (min)*	*Underlag*
1	☐ Fotballtrening ☐ Annen trening			☐ Gress ☐ Kunstgress ☐ Annet
	☐ Fotballtrening ☐ Annen trening ☐ Seriekamp ☐ Cupkamp ☐ Annen kamp			☐ Gress ☐ Kunstgress ☐ Annet
2	☐ Fotballtrening ☐ Annen trening			☐ Gress ☐ Kunstgress ☐ Annet
	☐ Fotballtrening ☐ Annen trening ☐ Seriekamp ☐ Cupkamp ☐ Annen kamp			☐ Gress ☐ Kunstgress ☐ Annet
3	☐ Fotballtrening ☐ Annen trening			☐ Gress ☐ Kunstgress ☐ Annet
	☐ Fotballtrening ☐ Annen trening ☐ Seriekamp ☐ Cupkamp ☐ Annen kamp			☐ Gress ☐ Kunstgress ☐ Annet
4	☐ Fotballtrening ☐ Annen trening			☐ Gress ☐ Kunstgress ☐ Annet
	☐ Fotballtrening ☐ Annen trening ☐ Seriekamp ☐ Cupkamp ☐ Annen kamp			☐ Gress ☐ Kunstgress ☐ Annet
5	☐ Fotballtrening ☐ Annen trening			☐ Gress ☐ Kunstgress ☐ Annet
	☐ Fotballtrening ☐ Annen trening ☐ Seriekamp ☐ Cupkamp ☐ Annen kamp			☐ Gress ☐ Kunstgress ☐ Annet
6	☐ Fotballtrening ☐ Annen trening			☐ Gress ☐ Kunstgress ☐ Annet
	☐ Fotballtrening ☐ Annen trening ☐ Seriekamp ☐ Cupkamp ☐ Annen kamp			☐ Gress ☐ Kunstgress ☐ Annet
7	☐ Fotballtrening ☐ Annen trening			☐ Gress ☐ Kunstgress ☐ Annet
	☐ Fotballtrening ☐ Annen trening ☐ Seriekamp ☐ Cupkamp ☐ Annen kamp			☐ Gress ☐ Kunstgress ☐ Annet
8	☐ Fotballtrening ☐ Annen trening			☐ Gress ☐ Kunstgress ☐ Annet
	☐ Fotballtrening ☐ Annen trening ☐ Seriekamp ☐ Cupkamp ☐ Annen kamp			☐ Gress ☐ Kunstgress ☐ Annet
9	☐ Fotballtrening ☐ Annen trening			☐ Gress ☐ Kunstgress ☐ Annet
	☐ Fotballtrening ☐ Annen trening ☐ Seriekamp ☐ Cupkamp ☐ Annen kamp			☐ Gress ☐ Kunstgress ☐ Annet
10	☐ Fotballtrening ☐ Annen trening			☐ Gress ☐ Kunstgress ☐ Annet
	☐ Fotballtrening ☐ Annen trening ☐ Seriekamp ☐ Cupkamp ☐ Annen kamp			☐ Gress ☐ Kunstgress ☐ Annet
11	☐ Fotballtrening ☐ Annen trening			☐ Gress ☐ Kunstgress ☐ Annet
	☐ Fotballtrening ☐ Annen trening ☐ Seriekamp ☐ Cupkamp ☐ Annen kamp			☐ Gress ☐ Kunstgress ☐ Annet
12	☐ Fotballtrening ☐ Annen trening			☐ Gress ☐ Kunstgress ☐ Annet
	☐ Fotballtrening ☐ Annen trening ☐ Seriekamp ☐ Cupkamp ☐ Annen kamp			☐ Gress ☐ Kunstgress ☐ Annet
13	☐ Fotballtrening ☐ Annen trening			☐ Gress ☐ Kunstgress ☐ Annet
	☐ Fotballtrening ☐ Annen trening ☐ Seriekamp ☐ Cupkamp ☐ Annen kamp			☐ Gress ☐ Kunstgress ☐ Annet
14	☐ Fotballtrening ☐ Annen trening			☐ Gress ☐ Kunstgress ☐ Annet
	☐ Fotballtrening ☐ Annen trening ☐ Seriekamp ☐ Cupkamp ☐ Annen kamp			☐ Gress ☐ Kunstgress ☐ Annet
15	☐ Fotballtrening ☐ Annen trening			☐ Gress ☐ Kunstgress ☐ Annet
	☐ Fotballtrening ☐ Annen trening ☐ Seriekamp ☐ Cupkamp ☐ Annen kamp			☐ Gress ☐ Kunstgress ☐ Annet
16	☐ Fotballtrening ☐ Annen trening			☐ Gress ☐ Kunstgress ☐ Annet
	☐ Fotballtrening ☐ Annen trening ☐ Seriekamp ☐ Cupkamp ☐ Annen kamp			☐ Gress ☐ Kunstgress ☐ Annet
17	☐ Fotballtrening ☐ Annen trening			☐ Gress ☐ Kunstgress ☐ Annet
	☐ Fotballtrening ☐ Annen trening ☐ Seriekamp ☐ Cupkamp ☐ Annen kamp			☐ Gress ☐ Kunstgress ☐ Annet
18	☐ Fotballtrening ☐ Annen trening			☐ Gress ☐ Kunstgress ☐ Annet
	☐ Fotballtrening ☐ Annen trening ☐ Seriekamp ☐ Cupkamp ☐ Annen kamp			☐ Gress ☐ Kunstgress ☐ Annet
19	☐ Fotballtrening ☐ Annen trening			☐ Gress ☐ Kunstgress ☐ Annet
	☐ Fotballtrening ☐ Annen trening ☐ Seriekamp ☐ Cupkamp ☐ Annen kamp			☐ Gress ☐ Kunstgress ☐ Annet
20	☐ Fotballtrening ☐ Annen trening			☐ Gress ☐ Kunstgress ☐ Annet
	☐ Fotballtrening ☐ Annen trening ☐ Seriekamp ☐ Cupkamp ☐ Annen kamp			☐ Gress ☐ Kunstgress ☐ Annet
21	☐ Fotballtrening ☐ Annen trening			☐ Gress ☐ Kunstgress ☐ Annet
	☐ Fotballtrening ☐ Annen trening ☐ Seriekamp ☐ Cupkamp ☐ Annen kamp			☐ Gress ☐ Kunstgress ☐ Annet
22	☐ Fotballtrening ☐ Annen trening			☐ Gress ☐ Kunstgress ☐ Annet
	☐ Fotballtrening ☐ Annen trening ☐ Seriekamp ☐ Cupkamp ☐ Annen kamp			☐ Gress ☐ Kunstgress ☐ Annet
23	☐ Fotballtrening ☐ Annen trening			☐ Gress ☐ Kunstgress ☐ Annet
	☐ Fotballtrening ☐ Annen trening ☐ Seriekamp ☐ Cupkamp ☐ Annen kamp			☐ Gress ☐ Kunstgress ☐ Annet
24	☐ Fotballtrening ☐ Annen trening			☐ Gress ☐ Kunstgress ☐ Annet
	☐ Fotballtrening ☐ Annen trening ☐ Seriekamp ☐ Cupkamp ☐ Annen kamp			☐ Gress ☐ Kunstgress ☐ Annet
25	☐ Fotballtrening ☐ Annen trening			☐ Gress ☐ Kunstgress ☐ Annet
	☐ Fotballtrening ☐ Annen trening ☐ Seriekamp ☐ Cupkamp ☐ Annen kamp			☐ Gress ☐ Kunstgress ☐ Annet
26	☐ Fotballtrening ☐ Annen trening			☐ Gress ☐ Kunstgress ☐ Annet
	☐ Fotballtrening ☐ Annen trening ☐ Seriekamp ☐ Cupkamp ☐ Annen kamp			☐ Gress ☐ Kunstgress ☐ Annet
27	☐ Fotballtrening ☐ Annen trening			☐ Gress ☐ Kunstgress ☐ Annet
	☐ Fotballtrening ☐ Annen trening ☐ Seriekamp ☐ Cupkamp ☐ Annen kamp			☐ Gress ☐ Kunstgress ☐ Annet
28	☐ Fotballtrening ☐ Annen trening			☐ Gress ☐ Kunstgress ☐ Annet
	☐ Fotballtrening ☐ Annen trening ☐ Seriekamp ☐ Cupkamp ☐ Annen kamp			☐ Gress ☐ Kunstgress ☐ Annet
29	☐ Fotballtrening ☐ Annen trening			☐ Gress ☐ Kunstgress ☐ Annet
	☐ Fotballtrening ☐ Annen trening ☐ Seriekamp ☐ Cupkamp ☐ Annen kamp			☐ Gress ☐ Kunstgress ☐ Annet
30	☐ Fotballtrening ☐ Annen trening			☐ Gress ☐ Kunstgress ☐ Annet
	☐ Fotballtrening ☐ Annen trening ☐ Seriekamp ☐ Cupkamp ☐ Annen kamp			☐ Gress ☐ Kunstgress ☐ Annet
31	☐ Fotballtrening ☐ Annen trening			☐ Gress ☐ Kunstgress ☐ Annet
	☐ Fotballtrening ☐ Annen trening ☐ Seriekamp ☐ Cupkamp ☐ Annen kamp			☐ Gress ☐ Kunstgress ☐ Annet

Appendix 8

Injury registration form

INJURY REGISTRATION FORM

SENTER FOR Idrettsskadeforskning KLOKE AV SKADE

A. PLAYER INFORMATION

Name:	Date of birth:
Club:	Phone number:

B. INJURY DATA

Injury definition: when the player is unable to take full part in training and match at least one day beyond the occurence of the injury.

1) *Acute injuries* – the injury is a result of a sudden, identifiable event
2) *Overuse injuries* – the onset is gradual and not related to one specific event

Date of injury: Injured side: 1☐ R 2☐ L 3☐ None	Activity: 1☐ Match 2☐ Training	Injury type: 1☐ Acute injury 2☐ Overuse injury 3☐ Other	Injury history: 1☐ New injury 2☐ Reinjury Months since last injury...... 3☐ Exacerbation

MATCH INJURIES: Type of match: 1☐ League match 2☐ Cup match 3☐ European Leauge 4☐ National team 5☐ Training match	TRAINING INJURIES: Type of training: 1☐ Ball practice 2☐ Strength training 3☐ Endurance training 4☐ Other	PLAYING SURFACE: 1☐ Grass 2☐ Artificial turf 3☐ Other (type?)…………

Player position (at the time of injury):
1☐ Goalkeeper 2☐ Defender 3☐ Wingback 4☐ Midfielder 5☐ Forward 6☐ Striker

Injured body part: 1☐ Hode/ansikt 2☐ Cervikalcolumna/nakke/hals 3☐ Skulder inkl. kragebein 4☐ Overarm 5☐ Albue 6☐ Underarm 7☐ Håndledd 8☐ Fingre 9☐ Brystkasse inkl. indre organer 10☐ Mageregion inkl. indre organer 11☐ Brystrygg 12☐ Lumbalrygg 13☐ Bekken 14☐ Hofte/lyske 15☐ Lår 16☐ Kne 17☐ Legg 18☐ Ankel 19☐ Fot/fotrot/tær 20☐ Annet	Inury type: 1☐ Fraktur 2☐ Vekstsoneskade/avulsjon 3☐ Stressfraktur 4 ☐ Pseudartrose 5☐ Luksasjon 6☐ Subluksasjon/instabilitet 7☐ Ledd- distorsjon 8☐ Ligamentskade 9☐ Synovitt/leddsmerte 10☐ Bruskskade 11 ☐ Artrose 12☐ Hematom 13☐ Kutt/sår 14 ☐ Sene/slimpose 15☐ Seneruptur 16☐ Muskelskade 17☐ Muskulære triggerpunkt(er) 18☐ Nerveskade 19☐ Karskade 20 ☐ Smerte INA 21☐ Sykdom/infeksjon 22☐ Tumor 23☐ Medfødt skade/defekt 24☐ Annet

Orchard injury classification:	Diagnosis:

When was the player able to participate fully in training and match?
1☐ 1-3 days 2☐ 4-7 days 3☐ 8-28 days 4☐>28 days 5☐ No absence

Recorded by:	Date:	Signature: