Risk factors for injury in men´s professional football

Karolina Kristenson
"Nothing in life is to be feared, it is only to be understood.  
Now is the time to understand more, so that we may fear less." / Marie Curie
PREFACE

I grew up on the county side in Sweden, in a place called Gammalkil. As a kid in Gammalkil you play football, and so did I. When I was 15, the elite club in the region, BK Kenty (later Linköping Football Club), invited me to participate in a try-out match. After this match, to my surprise, they offered me a first-team contract. BK Kenty played at that time in the women’s first league in Sweden, and I had not even played senior football. At first, I was reluctant to leave my team-mates, but I was honoured by the attention from the big club and I accepted the offer. Suddenly, I trained 5-6 days a week with players that were double my age, and I was by far the worst player in the team (no modesty). The first year was really tough, and I often wondered why I was doing this and whether it was worth the sacrifice. Then, eventually step-by-step, I worked my way into the team, and I started to enjoy it. Sorry, that is an understatement. I loved it. For a 5-year period, football became my first priority in life, and my teammates became my extended family. Unfortunately, after a couple of years I started to sustain injuries that hassled me and left me without a club contract. Naturally, I gained an interest in why injuries happen and how they can be prevented. I started to study medicine, with the intention to learn in debt about sport injuries; but semester-by-semester I was thrown into new aspects of the human body to discover, little by little forgetting why I actually started studying medicine in the first place. One day, four years into medical school, I received a phone call from my former team doctor, Jan Ekstrand. He was about to start up a new project in football injury epidemiology and wondered if I was interested to take part. How could I say no to this? Here, a journey started for me that has been ongoing for the past six years: The transition from the football player to the football researcher. What I have found is that a lot of things that are uniformly accepted among football players and coaches are probably not true. Actually, most of the hypotheses that I set up within this thesis have turned out to be false. I learned that research is a lot about “killing your darling”, meaning letting go of the things you thought were one way, when proved that they aren’t. Also, I have learned that the same principles follow in football research as in football play: a) it is worth it to hang in there through the tough times, and b) team work is everything!

/Karolina Kristenson, Linköping, March 20, 2015
TABLE OF CONTENT

INTRODUCTION 11
  The health paradox in sports 11
  Professional football 11
    UEFA Champions League 11
    Swedish and Norwegian football leagues 12
  Rationale for study setting 12
  Grading quality of evidence 13

LIST OF PAPERS 15

DESCRIPTION OF CONTRIBUTION 16

ABBREVIATIONS 18

BACKGROUND 21
  Sports injury surveillance 21
    Injury definitions 22
    Injury mechanism and severity 23
    Exposure definitions 23
    Injury rate and injury risk measurement definitions 24
  Injury epidemiology in football 24
    Time-loss injury rate 24
    Injury pattern 25
    Methodological aspects in injury epidemiology 25
  Risk factors for football injury 26
    Risk factor model 26
    Internal risk factors for injury in men’s professional football 28
    External risk factors for injury in men’s professional football 33
  Artificial turf and injury rates in football 37
    Injury rate on AT vs. NG – critical review and evidence grading 37
    Professional football 40
    Amateur football 41
    Adolescent football 41
    Overuse injuries and AT 42
    Surface shifts and play on unaccustomed surfaces 43
    Climate at club home venue 43

AIMS OF THE THESIS 45

METHODS 47
  Study design 47
  Data collection 47
Study forms 47
Definitions 47
  Injury data 47
  Exposure data 47
  Paper-specific definitions 48

SETTING AND PARTICIPANTS 49
Paper I 49
Paper II 49
Paper III 49
Paper IV 49

DATA ANALYSIS AND STATISTICS 53
Anthropometrics and exposures 53
Injury rate 54
  Injury rate on AT compared to NG 54
  Injury rate for AT clubs compared to NG clubs 54
  Injury rate on accustomed compared to unaccustomed surfaces 54
  Injury rate in clubs from different climate zones 54
Cumulative overuse injury incidence 55
Generalised estimating equations 55
Survival analysis 56
Agreement analysis 56

ETHICS 57

RESULTS 59
Paper I 59
  Newcomers compared to established players 59
  Multivariable risk factor analysis 59
Paper II 59
  Injury rate on AT compared to NG 59
  Injury rate for AT clubs compared to NG clubs 59
Paper III 60
  Surface shifts 60
  Climate zones 61
Paper IV 61
  Injury capture rate 61
  Agreement in injury categorisation 61

DISCUSSION 63
Newcomers – young and healthy or more hesitant to seek medical assistance? 63
Lower injury rates in the youngest age group 63
Lower injury rates for goalkeepers 64
Acute injury rate on AT compared to NG – where are we now? 64
  Aggregated analysis of injury pattern on AT compared to NG 65
INTRODUCTION
The health paradox in sports
Regular moderate-intensity physical activity reduces morbidity and mortality in numerous diseases via primary, secondary and tertiary effects (Matheson et al., 2011). Studies have also showed that physical activity by playing football stimulates musculoskeletal, metabolic and cardiovascular adaptations of importance for health and thus reduces the risk of developing life-style diseases (Krstrup et al., 2010). Football (often named soccer in American literature) is the largest sport in the world with approximately 265 million licensed players (FIFA, 2006), and has major potential in global health promotion efforts.

However, participating in sports is also associated with an inherent risk of sustaining injury. In Scandinavian settings, sports injuries annually constitute one-fifth of all injuries requiring medical care at health centres or emergency departments (de Loës M, 1990) and through the popularity of football in the Scandinavian countries, a majority of these injuries are football-related (Lindqvist et al., 1996). In professional football, the risk of sustaining an injury is substantial. The overall risk of injury to professional footballers has been shown to be around 1000 times higher times higher than for industrial occupations generally regarded as in high risk (Drawer and Fuller, 2002). Also, about half of professional football players retire from football due to an injury (Drawer and Fuller, 2001), and professional football players run an increased risk for long-term consequences such as early-onset osteoarthritis in the hip and knee joints (Lindberg et al., 1993; von Porat et al., 2004).

Professional football
According to the International Federation of Association Football (FIFA) regulations, players participating in organised football are either amateurs or professionals. A professional is a player who has a written contract with a club and is paid more for his/her footballing activity than the expenses he/she effectively incurs. All other players are considered to be amateurs (FIFA, 2013). The first and second men’s leagues, and the women’s first league in Sweden and Norway are defined as elite level. The participating elite players within this thesis are all professional and thus the term professional football is used consistently.

UEFA Champions League
Organised by the Union of European Football Associations (UEFA), the UEFA Champions League (UCL) is an annual football tournament. It was introduced in 1992, replacing the European Champions Clubs Cup (European Cup) that had run since 1955. The European Cup
was a straight knockout tournament open to the campaign winners from each country. When the UCL was introduced, a group stage was added to the competition, which allowed more clubs to participate. Today, the strongest European national leagues can send up to four clubs to the competition. In its current format, the UCL starts in July with three knockout-qualifying rounds, and one subsequent play-off round. From this, 10 surviving clubs enter the group stage, together with 22 clubs qualified in advance. These 32 clubs are allocated into eight groups with four clubs in each group, and play each other in a double round-robin system. The group winners and runners-up proceed to the knockout phase, and the final is played in May each year after the end of the national leagues and thus concludes the club season.

**Swedish and Norwegian football leagues**
The men’s first league in Sweden is named Allsvenskan and has existed since 1924. It consists of 16 clubs that play two matches against each other every season, one at the home venue and one away. The men’s first league in Norway is called Tippeligaen, named after its main sponsor since 1991. The Norwegian league has existed since 1937 and nowadays comprises 16 clubs. Tippeligaen is also played in a league where all clubs meet twice each season. In both Allsvenskan and Tippeligaen, the pre-season starts in early January and the competitive season begins from mid-March/early April and runs until mid-November. The leagues are similar in standard, Allsvenskan has a European ranking of 28, and Tippeligaen has a European ranking of 29, according to the UEFA coefficient 2010-2011.

**Rationale for study setting**
Male professional football clubs in both the UCL and in Scandinavia have access to medical support consisting of various professions, including physicians and physiotherapists, and sometimes also other professions, where at least one medical staff member always is present during training sessions and matches. This medical support, in this thesis called the medical team, can thus facilitate a detailed injury and exposure registration, which is not always possible in female professional, amateur or youth settings where medical support is less developed or non-existent. In addition, the injury rate is highest in men’s professional football, which in itself justifies injury surveillance and preventive actions. The high injury rate also enables samples sizes of injuries that are large enough to study injury characteristics in detail and with sufficient statistical power. Therefore, male professional football is a setting suitable for studies concerning specific injury risk factor analysis. Owing to the Scandinavian climate, artificial turfs are quite common in Allsvenskan and Tippeligaen. Thus, the Scandinavian setting is suitable for studies evaluating the injury risk related to artificial turf.
Grading quality of evidence
The Grades of Recommendation, Assessment, Development and Evaluation (GRADE) Working Group developed a system for grading quality of evidence (Grade Working Group, 2004). The GRADE quality ratings range from high followed by, moderate, low and with very low as the lowest quality of evidence. A randomised controlled trial (RCT) enters at the high quality level, but can be degraded due to: limitations in study design, indirectness of evidence, unexplained heterogeneity of results, imprecision in results or high probability of publication bias. Observational studies enter the grading system at the low quality level, but can be both downgraded (due to the same limitations as for RCTs) or upgraded due to factors that increase the study quality; large magnitude effects, all plausible confounding factors taken into account, or dose-response gradient. Usually, quality ratings fall by one level for each factor, up to a maximum of three levels for all factors. If there are very severe problems for any one factor, studies may fall by two levels due to that factor alone (Grade Working Group, 2004).
LIST OF PAPERS

This thesis includes four papers based on three different prospective cohort studies on injury rates and injury characteristics in men’s professional football.


DESCRIPTION OF CONTRIBUTION

**Paper I**

Study design  Martin Hägglund, Markus Waldén, Jan Ekstrand
Data collection  Karolina Kristenson, Markus Waldén, Jan Ekstrand, Martin Hägglund.
Data analysis  Karolina Kristenson
Manuscript writing  Karolina Kristenson
Manuscript revision  Markus Waldén, Jan Ekstrand, Martin Hägglund.
Journal correspondence  Karolina Kristenson

**Paper II**

Study design  Karolina Kristenson, John Bjørneboe, Markus Waldén, Thor Einar Andersen, Jan Ekstrand, and Martin Hägglund.
Data collection  Karolina Kristenson, John Bjørneboe
Data analysis  Karolina Kristenson
Manuscript writing  Karolina Kristenson
Manuscript revision  John Bjørneboe, Markus Waldén, Thor Einar Andersen, Jan Ekstrand, Martin Hägglund.
Journal correspondence  Karolina Kristenson

**Paper III**

Study design  Karolina Kristenson, Martin Hägglund
Data collection  Karolina Kristenson, John Bjørneboe
Data analysis  Karolina Kristenson
Manuscript writing  Karolina Kristenson
Manuscript revision  John Bjørneboe, Markus Waldén, Thor Einar Andersen, Jan Ekstrand, Martin Hägglund.
Journal correspondence  Karolina Kristenson
Paper IV

<table>
<thead>
<tr>
<th>Task</th>
<th>Responsible</th>
</tr>
</thead>
<tbody>
<tr>
<td>Study design</td>
<td>Karolina Kristenson</td>
</tr>
<tr>
<td>Prospective data collection</td>
<td>John Bjørneboe, Martin Hägglund</td>
</tr>
<tr>
<td>Retrospective data collection</td>
<td>Karolina Kristenson</td>
</tr>
<tr>
<td>Data analysis</td>
<td>Karolina Kristenson</td>
</tr>
<tr>
<td>Manuscript writing</td>
<td>Karolina Kristenson</td>
</tr>
<tr>
<td>Manuscript revision</td>
<td>John Bjørneboe, Markus Waldén, Thor Einar Andersen, Jan Ekstrand, Martin Hägglund</td>
</tr>
<tr>
<td>Journal correspondence</td>
<td>Karolina Kristenson</td>
</tr>
</tbody>
</table>
ABBREVIATIONS

The following abbreviations, listed in alphabetical order, are used in the thesis.

ACL  Anterior cruciate ligament
ANOVA  Analysis of variance
AT  Artificial turf
BMI  Body mass index
CI  Confidence interval
CIR  Cumulative incidence rate
F  Female
FIFA  International Federation of Association Football (Fédération Internationale de Football Association)
FRG  Football Research Group
GEE  Generalised estimating equation
GRADE  Grades of recommendation, assessment, development and evaluation
HR  Hazard ratio
IBE  Individual-based exposure
IR  Injury rate (injuries/1000 hours exposure)
κ  Kappa coefficient
KOOS  Knee osteoarthritis outcome score
M  Male
MCL  Medial collateral ligament of the knee
NCMSTI  Non-contact musculoskeletal soft tissue injury
NFIA  Nordic Football Injury Audit
NG  Natural grass
OR  Odds ratio
<table>
<thead>
<tr>
<th>Acronym</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>OSTRC</td>
<td>Oslo Sports Trauma Research Center</td>
</tr>
<tr>
<td>PABAK</td>
<td>Prevalence adjusted bias adjusted kappa</td>
</tr>
<tr>
<td>RCT</td>
<td>Randomised controlled trial</td>
</tr>
<tr>
<td>RR</td>
<td>Rate ratio</td>
</tr>
<tr>
<td>SD</td>
<td>Standard deviations</td>
</tr>
<tr>
<td>SNP</td>
<td>Single nucleotide polymorphisms</td>
</tr>
<tr>
<td>TBE</td>
<td>Team-based exposure</td>
</tr>
<tr>
<td>TRIPP</td>
<td>Translating research into injury prevention practice</td>
</tr>
<tr>
<td>UEFA</td>
<td>Union of European Football Associations (Union des Associations Européennes de Football)</td>
</tr>
<tr>
<td>UCL</td>
<td>UEFA Champions League</td>
</tr>
</tbody>
</table>
BACKGROUND

Sport injury surveillance

In 1992, a systematic approach to sport injury prevention was introduced by Willem van Mechelen and colleagues (van Mechelen et al., 1992). This approach (Figure 1) was named the sequence of prevention and is one of the most cited studies in the field of sports medicine. The first step involves describing the extent of the problem. Here epidemiological studies are used, preferably prospective cohort studies, presenting injury rates and injury pattern in the area of interest. The second step is to determine the causes of injury by analysing risk factors and injury mechanisms. The third step is to develop and introduce preventive strategies, and the fourth is to measure their efficacy by repeating the first step or preferably by carrying out an RCT. In 2006, Caroline Finch expanded this model with two extra steps stressing the fact that only interventions that actually are adopted in real life sports setting can prevent injuries (Finch, 2006). This model is named the Translating Research into Injury Prevention Practice (TRIPP) framework. The two extra steps include describing the intervention context (step 5), and implementing the intervention in the real world context and evaluating its effectiveness (step 6). This thesis will mainly focus on the second step in the sequence of prevention, by evaluating potential internal (Paper I) and external risk factors for injury (Paper II and Paper III).

**Figure 1.** The sequence of prevention described by van Mechelen et al. in Sports Medicine 1992. Here illustrated by a figure published is British Journal of Sports Medicine. Re-printed with permission of the journal.
**Injury definitions**

The operational definitions of injury previously used in football injury epidemiology vary on a broad spectrum of severity from injuries with insurance claim submitted, injuries resulting in hospital treatment, in time-loss from football participation, in medical attention, and any physical complaint. A draw-back with the first two definitions is that they only capture the most severe injuries and not all injuries that are important from a performance perspective in professional football. At the other end of the spectrum, the *any physical complaint* definition includes all physical complaints regardless of their consequences. This definition is perhaps the most valid in an ideal setting, especially when studying overuse injuries. However, the drawback is that it might lead to a low level of reliability since no limit is given where to draw the cut off for what would be regarded as an injury in relation to minor complaints that do not affect player health or performance (e.g. a minor bruise). The *medical attention* definition of injury includes all injuries where athletes seek attention from a qualified medical practitioner. This definition gives therefore some sort of filter for these minor complaints to be included as injuries. However, a drawback is that the number of injuries recorded with this definition will vary with access and activity from the medical practitioner. The number of injuries recorded will also vary depending on the level of play since young players and amateur players sometimes only meet medical personnel when visiting the hospital (meaning that medical attention equals the hospital treatment definition of injury). In professional settings, clubs most often have employed medical personnel, and this proximity to the rater will lead to less severe injuries captured in elite setting compared to amateur settings. In addition, this definition is also dependent on the health seeking behaviour in the athlete and does not include the sport relevance. The most common definition in football injury epidemiology today, and the definition used in this thesis, is the *time-loss* injury definition. Here all injuries leading to the athlete being unable to fully participate in normal training and competition are included. The greatest advantage with this approach is that it includes injuries that in some way affect players’ health and performance. This approach is also relevant in team sport settings such as football, where training sessions are usually planned on a team level, setting a functional demand on the player that is reasonable to be fulfilled if the player is not injured. The main drawbacks to this definition is that it depends on the frequency of training sessions and access to medical personnel (which is more of a concern in youth and amateur settings), but also the pain threshold and motivation of the player as well as the medical/rehabilitation philosophy in the club (if a player with minor complaints will be taken out from the team training in an early stage or not). The time-loss definition may also affect players in different
playing positions to a different extent. For example, an upper extremity injury (e.g. a finger sprain) will not affect an outfield player to a greater extent, probably not even leading to absence from training or match and thus will not constitute an injury. However, for a goalkeeper, this injury may be more likely to affect performance and therefore also increase the probability to miss out of football, and be regarded as injured. All in all, no ideal definition exists and the consensus statement, established in 2006 for recommendations of definitions used in football injury epidemiology, therefore recommends three different definitions to be used, depending on the setting and purpose of study: any physical complaint, medical attention or time-loss (Fuller et al., 2006).

### Injury mechanism and severity

Injuries are often also classified according to their injury mechanism, into traumatic injuries (acute onset) or overuse injuries (gradual onset). An acute injury refers to an injury resulting from a specific, identifiable event, and an overuse injury to one caused by repeated micro trauma without a single, identifiable event responsible for the injury (Fuller et al., 2006). However, overuse injuries have received little attention in the sports injury prevention literature compared to acute injuries such as anterior cruciate ligament ruptures and ankle-ligament sprains (Clarsen et al., 2013). This is probably due to their typical presentation and characteristics with minor symptoms initially and insidious onset, which make them difficult to record properly in epidemiological studies.

According to van Mechelen, sport injury severity can be described using at least six different criteria: the nature of the sports injury; the duration and nature of treatment; sporting time-loss; working time-loss; permanent damage; and cost (van Mechelen et al., 1992). By far the most common definition in the existing literature is sporting time-loss, which also is used within this thesis. Here, severity is graded based on the number of days an athlete is absent from matches and training due to an injury.

### Exposure definitions

To be able to estimate the risk for sustaining a football injury, one must not only register the number of injuries occurring during study period, but also the exposure for injury (van Mechelen et al., 1992). The consensus statement, recommends two different methods for recording player exposure: individual-based registration of exposure (IBE) or team-based registration of exposure (TBE) (Fuller et al., 2006). IBE includes all players’ individual time of participation in each training session and match, whereas TBE registers a sum of exposure.
for each activity based on the number of players participating and the length of the activity (Fuller et al., 2006). Collecting exposure on team-basis is less time-consuming for the club contact persons and might therefore attract more clubs to volunteer in taking part in research projects. However, it is not possible to conduct an exposure-adjusted risk factor analysis on individual level with TBE (Hägglund et al., 2005).

Injury rate and injury risk measurement definitions
In the first step in the sequence of prevention the extent of the problem is described by presenting relevant injury rates. The most common and recommended (Fuller et al., 2006) method is to present injury incidences defined as the number of injuries recorded per 1000 exposure hours (Lindenfeldt et al., 1994). This figure for injury incidence is referred as the injury rate to in this thesis. Since overuse injuries often are associated with longstanding symptoms, evaluation using injury rate only can lead to an underestimation of injury magnitudes. It is therefore recommended that overuse injury rates should be presented using injury risks defined as the proportion of athletes affected by problems at any given time (Bahr, 2009). This can be done using injury prevalence (number of individuals currently suffering from injury within the population at risk). In this thesis, this is achieved by calculating cumulative injury incidences, defined as number of individuals sustaining a new injury within a given time period, in the population at risk.

Injury epidemiology in football
Continuous injury surveillances (studying a league > 1 season) in men’s professional football have been carried out, for club football, in England (Hawkins and Fuller 1999), Norway (Andersen et al., 2004; Bjørneboe et al., 2014), Sweden (Hägglund et al., 2006), and in the UCL Injury Study (Ekstrand et al., 2011b). In addition, injury studies have also been carried out in tournament football at the FIFA senior World Cups and youth World Championships (Junge and Dvorak, 2013), Olympic Games (Junge and Dvorak, 2013), UEFA youth and senior European Championships (Hägglund et al., 2009b; Waldén et al., 2007), and the Asian Cup and Asian U-19 Championships (Yoon et al., 2004).

Time-loss injury rate
The injury rate in male club professional football ranges from 15.9-27.7 injuries/1000 match hours, and 1.9-5.3 injuries/1000 training hours (Andersen et al., 2004; Bjørneboe et al., 2014; Hawkins and Fuller 1999; Hägglund et al., 2006; Ekstrand et al., 2011b). In tournament
football, the training injury rates are similar (2.1-4.6/1000 training hour), while the match injury rates usually are increased compared to club football, ranging from 33.1-45.8/1000 match hours (Hägglund et al., 2009b; Junge and Dvorak, 2013; Waldén et al., 2007; Yoon et al., 2004).

The injury rates in male youth (Ergün et al., 2013; Junge et al., 2002; Junge et al., 2004; Owoeye et al., 2014), and amateur football (Herrero et al., 2014; Sousa et al., 2014; van Beijsterveldt et al., 2013) are in general lower compared to male professional level (match injury rate 1.15-32.2/1000 hours; training injury rate 0.3-5.7/1000 hours). The match injury rate seems to progressively increase with age among young players (Faude et al., 2013), and the highest injury rates in youth football is found in youth elite settings (Ergün et al., 2013).

The total match injury rates in female professional club football (12.9-23.6/1000 hours) are lower compared to male professional football (Faude et al., 2005; Hägglund et al., 2009a; Jacobson and Tegner, 2007; Nilstad et al., 2014; Tegnander et al., 2008). However, the injury rate of club training injuries, severe injuries and injuries sustained during tournaments is similar in male and female professional football (Faude et al., 2005; Hägglund et al., 2009a; Jacobson and Tegner, 2007; Nilstad et al., 2014; Tegnander et al., 2008; Waldén et al., 2007).

**Injury pattern**

When evaluating the continuous injury surveillances performed in male professional football (Andersen et al., 2004; Bjørneboe et al., 2014; Hawkins and Fuller, 1999; Hägglund et al., 2006; Ekstrand et al., 2011b), a majority of injuries have an acute onset (61-72%) while fewer are classified as overuse injuries (28-39%). The most common injury type in all studies is muscle injury (19-41% of all injuries), ligament injury (15-20%) and contusion (15-20%). Regarding injury location, a clear predominance is found among lower extremity injuries, most affecting the thigh (22-23%), followed by knee (14-18%), hip/groin (11-19%), and ankle injuries (9-18%). The majority of injuries result in absence periods shorter than one week (49-51%), while 11-16% of injuries are regarded as severe with absence periods > 28 days.

**Methodological aspects in injury epidemiology**

Even though the field of football injury epidemiology research has recently expanded, few studies have investigated the methodological aspects in their data recording. One study of Czech amateur football found that retrospective player interviews at the end of the season only captured about 10-30% of injuries, compared to weekly prospective injury assessment by medical personnel (Junge and Dvorak, 2000). On the other hand, a study of male professional
football players suggested that prospective injury recordings by medical staff (using TBE) underestimated the injury rate by at least one-fifth compared to a structured retrospective player interview for injuries sustained during the last three months period (Bjørneboe et al., 2011). Another Norwegian study found that medical staff reporting missed approximately two thirds of all injuries, and 50% of all severe injuries compared to individual self-reported registration through text messaging in female professional football (Nilstad et al., 2012). It has been suggested that prospective recordings using IBE would increase the capture rate of injuries, since it allows the study group to verify injury reports received against injury absence periods registered in the player attendance (Hägglund et al., 2005; Bjørneboe et al., 2011), yet this has never been directly evaluated. Also, correct classification of injury categories (e.g. injury type, injury location) is a prerequisite for a valid injury audit (Bahr and Holme, 2003), but no study has investigated the inter-rater agreement in injury categorisation between different football injury audits.

Risk factors for football injury

Risk factor model
In 1994, Willem Meeuwisse presented a multifactorial model to assess risk factors and causation for sport injuries (Meeuwisse, 1994). In this model, a risk factor is defined as a factor associated with the injury, and this definition is also used within this thesis. Furthermore, Meeuwisse separated risk factors into internal and external factors. Internal risk factors (also called individual or person-related risk factors) are factors based within the athlete, while external (environmental) risk factors are factors having impact “from without”. Examples of internal risk factors are player age, playing position, strength and flexibility; and examples of external risk factors are weather, field conditions, surface types, rules and equipment. In the multifactorial model of athlete injury aetiology (Meeuwisse, 1994), Meeuwisse theorises that numerous internal risk factors may predispose an athlete to injury. In addition, external risk factors can facilitate the manifestation of the injury. However, although a risk factor may be necessary for an injury outcome, they are seldom sufficient by themselves to cause an injury. Meeuwisse argues that an inciting event is the final link in the chain of causation in the definitive onset of the injury. An example of an inciting event from football context could be a tackle from a defender that hits the medial side of the opponent’s ankle, causing a forced inversion of the ankle and consequently a lateral ligament injury. Using this injury example, an internal risk factor for injury could be a history of previous
ligament injuries in the same ankle, leading to reduced proprioception; an external risk factor for injury could be an uneven playing surface that may facilitate ankle supination. Roald Bahr and Tron Krosshaug subsequently expanded this model (Bahr and Krosshaug, 2005), to include a more comprehensive approach to the description of the inciting event from a biomechanical point of view (Figure 2).

**Figure 2.** Multifactorial model of athlete injury aetiology, initially described by Meeuwisse in 1994 and expanded by Bahr and Krosshaug in 2005. Re-printed with permission of the British Journal of Sports Medicine.
Internal risk factors for injury in men’s professional football

Previous injury
Several studies have showed that previous injury is an important internal risk factor for injury. Hägglund et al. studied the Swedish first league for two consecutive seasons 2001-2002. Using multivariable analysis, previous injury in the first season was identified as a significant risk factor for injury in the subsequent season. This was particularly evident for hamstring muscle injuries (Hägglund et al., 2006). A one-season follow up study with pre-season screening in Icelandic football evaluated several internal risk factors for injury. In this study, previous injury was identified as a significant risk factor for hamstring strain, groin strain, knee sprain and ankle sprain (Árnason et al., 2004a). Engebretsen et al. evaluated internal risk factors for injury among professional and amateur Norwegian players. They included specific information on previous injury, specific function scores, balance tests and a clinical examination. Previous injury was again the main predictor for acute ankle injuries (Engebretsen et al., 2010a), groin injuries (Engebretsen et al., 2010b), and hamstring injuries (Engebretsen et al., 2010c). Similarly, multivariable analyses in UCL settings indicated that having a previous identical injury in the preceding season increased injury rates significantly for adductor, hamstring, quadriceps, and calf injuries (Hägglund et al., 2013a). In addition, studies in Swedish male professional level have identified previous anterior cruciate ligament (ACL) injury is a risk factor for a new knee injury, especially overuse injury (Waldén et al., 2006), and recent studies on UCL data have showed that that previous concussion is a risk factor for sustaining subsequent time-loss injury within the following year (Nordström et al., 2014).

Genotypic differences
Recently, studies in Spanish settings have identified that genetic variations may be a risk factor for non-contact musculoskeletal soft tissue injuries. In these studies, different single nucleotide polymorphisms (SNPs) in genes related to tissue recovery and tissue repair were correlated to injury type and injury severity in different ethnic groups. The frequency of the SNPs was found to vary between the different ethnic groups, and significant relations were found between different SNPs and injury outcome (Pruna et al., 2013; Pruna et al., 2015).

Psychological factors
Few studies have evaluated psychological risk factors for injury in men’s professional football. However, Ivarsson et al. studied a Swedish cohort and found that trait anxiety,
negative life event and daily hassles were significant predictors for injury (Ivarsson et al., 2013). In addition, Devantier studied Danish players and found that player ability to cope with adversity was a main predictor for injury occurrence (Devantier, 2011).

**Anthropometrics**
A risk factor study in Icelandic football found that players sustaining groin strain within a season had significantly higher percentage of body fat than the group without groin strains (Árnason et al., 2004a). Similarly, studies in UCL settings have found borderline significant association between increased weight and patellar tendinopathy (Hägglund et al., 2011). Other studies have evaluated the association between player height and weight and muscle injuries (Hägglund et al., 2013a), fifth metatarsal fractures (Ekstrand and van Dijk, 2013) and stress fractures (Ekstrand and Torstveit, 2012), all with non-significant results.

**Physical status**
A one-season follow-up study with pre-season screening in Icelandic football evaluated flexibility, leg extension power, jump height, peak oxygen uptake and joint stability as risk factors for football injury. Out of these, multivariable analysis identified only decreased range of motion in hip abduction as a risk factor for groin strain (Árnason et al., 2004a).

**Newcomers to professional football**
Players who are promoted from youth academies are exposed to several factors that may influence injury occurrence. These factors include, physical adaptation to new training methods, changes in training and match loads, lack of social support, and new relationships with players, coaches, technical staff, and medical staff. However, no previous study has investigated whether newcomers to professional football have a different injury rate than their team colleagues. Interestingly, a newly published study in Australian Rules football found an increased injury rate for players during their first year in the professional Australian football league compared to established players (Fortington et al., 2014).

**Player age**
Player age as potential risk factors for football injury in general has been evaluated previously in the literature, with conflicting results. One study detected increased injury rates in older players (Árnason et al., 2004a), while others reported no association between age and injury rates (Chomiak et al., 2000; Dauty et al., 2011; Hägglund et al., 2006; Hägglund et al., 2009a; Morgan and Oberlander, 2001). Inclusion of individual exposure to training and match play in the analyses is less common, and studies have often used different cut-offs for age.
categorisation (Árnason et al., 2004a; Hägglund et al., 2006). These are issues that may contribute to the contradictory findings regarding the association between age and injury rates in professional football.

Previous literature has found that the injury rate for specific injury types varies with age. Older age has been identified as a risk factor for Achilles tendon injuries (Gajhede et al., 2013) and calf injuries (Hägglund et al., 2013a). In contrast, younger age has been found to be associated with stress fractures (Ekstrand and Torstveit, 2012) and fifth metatarsal fractures (Ekstrand and van Dijk, 2013).

Playing position
Playing position as a risk factor for football injury in general has been evaluated previously but with conflicting results. Some studies showed no difference in injury rates between playing positions (Chomiak et al., 2000; Dauty et al., 2011; Morgan and Oberlander, 2001), while others found an increased injury rate for midfielders (Andersen et al., 2003; Árnason et al., 2004b), forwards (Andersen et al., 2004), and lower injury rates among goalkeepers (Aoki et al., 2012; Árnason et al., 2004b; Ryynänen et al., 2013c). Previous studies addressing playing position and injury rate are also limited by a lack of individual exposure registration, and many have small samples or have included match injuries only (Andersen et al., 2003; Andersen et al., 2004; Árnason et al., 2004a; Ryynänen et al., 2013c). In addition, any concomitant influence of player age and playing position on injury rates is not known, even though the age distribution often differs between playing positions (Bloomfield et al., 2006).

Similar to player age, playing position has been found to be a risk factor for specific football injuries. When studying lower extremity muscle injuries (Hägglund et al., 2013a) and MCL injuries of the knee (Lundblad et al., 2013), lower injury rates were found for goalkeepers compared to outfield players. In contrast, goalkeepers have been identified to have a higher rate of upper extremity injuries (Ekstrand et al., 2013), and defenders have been found to have the highest rate of head/neck injuries (Nilsson et al., 2013). Playing position was not associated with patellar tendinopathy injury rates (Hägglund et al., 2011).

Consequently, player age and playing position are two fundamental potential internal risk factors for football injury. However, to date studies with multivariable analysis using adequate registration of player exposure are lacking.
Table 1. Internal risk factors for football injury in men’s professional football

<table>
<thead>
<tr>
<th>Publication</th>
<th>Data collected</th>
<th>Setting</th>
<th>Risk factor studied</th>
<th>Injury outcome studied</th>
</tr>
</thead>
<tbody>
<tr>
<td>Andersen et al., 2004</td>
<td>2000</td>
<td>Norwegian first league</td>
<td>Playing position</td>
<td>Acute time-loss</td>
</tr>
<tr>
<td>Aoki et al., 2012</td>
<td>1993-2007</td>
<td>Japanese first league</td>
<td>Playing position</td>
<td>Acute match time-loss injury &gt; 7 days</td>
</tr>
<tr>
<td>Árnason et al., 2004a</td>
<td>1999</td>
<td>Icelandic first league</td>
<td>Height, weight, previous injury, flexibility, strength,</td>
<td>Time-loss injury</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>jump height, peak oxygen uptake, joint stability.</td>
<td></td>
</tr>
<tr>
<td>Árnason et al., 2004b</td>
<td>1999</td>
<td>Icelandic first league</td>
<td>Playing position, playing situations</td>
<td>Time-loss injury</td>
</tr>
<tr>
<td>Chomiak et al., 2000</td>
<td>Not presented</td>
<td>Czech players amateur to professional</td>
<td>Age, previous injury, joint/spine status, or inadequate treatment and rehabilitation of injuries</td>
<td>Severe injury</td>
</tr>
<tr>
<td>Dauty et al., 2011</td>
<td>1995-2010</td>
<td>Professional French club</td>
<td>Age, playing position</td>
<td>Time-loss injury &gt; 72 hours</td>
</tr>
<tr>
<td>Devanter 2011</td>
<td>2010</td>
<td>Danish first and second leagues</td>
<td>Psychological risk factors</td>
<td>Time-loss injury</td>
</tr>
<tr>
<td>Engebretsen et al., 2010a</td>
<td>2004</td>
<td>Norwegian amateur to professional</td>
<td>Previous injury, function score, clinical examination</td>
<td>Time-loss acute ankle injury</td>
</tr>
<tr>
<td>Engebretsen et al., 2010b</td>
<td>2004</td>
<td>Norwegian amateur to professional</td>
<td>Previous injury, function score, clinical examination</td>
<td>Time-loss groin injury</td>
</tr>
<tr>
<td>Engebretsen et al., 2010c</td>
<td>2004</td>
<td>Norwegian amateur to professional</td>
<td>Previous injury, function score, clinical examination</td>
<td>Time-loss hamstring injury</td>
</tr>
<tr>
<td>Engebretsen et al., 2011</td>
<td>2004</td>
<td>Norwegian amateur to professional</td>
<td>Previous injury, function score, clinical examination</td>
<td>Time-loss acute knee injury</td>
</tr>
<tr>
<td>Ekstrand and Torstveit 2012</td>
<td>2001-2009</td>
<td>European clubs</td>
<td>Age</td>
<td>Stress fracture</td>
</tr>
<tr>
<td>Ekstrand et al., 2013</td>
<td>2001-2011</td>
<td>European clubs</td>
<td>Playing position</td>
<td>Time-loss upper extremity injury</td>
</tr>
<tr>
<td>Ekstrand and van Dijk 2013</td>
<td>2001-2012</td>
<td>European clubs</td>
<td>Age, height, weight, BMI</td>
<td>Fifth metatarsal fracture</td>
</tr>
<tr>
<td>Gajhede-Knudsen et al., 2013</td>
<td>2001-2012</td>
<td>UCL</td>
<td>Age</td>
<td>Time-loss Achilles tendon injury</td>
</tr>
<tr>
<td>Hägglund et al., 2006</td>
<td>2001-2002</td>
<td>Swedish first league</td>
<td>Previous injury, age, height, weight, BMI</td>
<td>Time-loss injury</td>
</tr>
<tr>
<td>Hägglund et al., 2009a</td>
<td>2005</td>
<td>Swedish first league</td>
<td>Age</td>
<td>Time-loss injury</td>
</tr>
<tr>
<td>Hägglund et al., 2011</td>
<td>2001-2009</td>
<td>European clubs</td>
<td>Age, height, weight, playing position</td>
<td>Time-loss patellar tendinopathy</td>
</tr>
<tr>
<td>Hägglund et al., 2013a</td>
<td>2001-2010</td>
<td>UCL</td>
<td>Age, height, weight, playing position and previous muscle injury</td>
<td>Time-loss lower extremity muscle injury</td>
</tr>
<tr>
<td>Ivarsson et al., 2013</td>
<td>2010</td>
<td>Swedish first league</td>
<td>Psychological risk factors</td>
<td>Time-loss injury</td>
</tr>
<tr>
<td>Lundblad et al., 2013</td>
<td>2001-2012</td>
<td>UCL</td>
<td>Playing position</td>
<td>Time-loss MCL injury of the knee</td>
</tr>
<tr>
<td>Morgan and Oberlander, 2001</td>
<td>1996</td>
<td>American first league</td>
<td>Playing position, player age</td>
<td>Time-loss injury</td>
</tr>
<tr>
<td>Nilsson et al., 2013</td>
<td>2001-2010</td>
<td>UCL</td>
<td>Age, height, weight, playing position</td>
<td>Time loss head/neck injury</td>
</tr>
<tr>
<td>Nordström et al., 2014</td>
<td>2001-2012</td>
<td>UCL</td>
<td>Previous concussion</td>
<td>Time-loss injury</td>
</tr>
</tbody>
</table>
Pruna et al., 2013  Three seasons  Spanish first league club  Genotypic differences  NCMSTI
Pruna et al., 2015  Three seasons  Spanish first league club  Inter-racial genotypic differences  NCMSTI
Ryynänen et al., 2013c  2002, 2006, 2010  FIFA World Cup  Playing position  Medical attention injury
Waldén et al., 2006  2001  Swedish first league  Previous ACL injury  Time-loss knee injury

ACL, anterior cruciate ligament; FIFA, International Federation of Association Football; KOOS, Knee Osteoarthritis Outcome Score; NCMSTI, Non-contact musculoskeletal soft tissue injury; MCL, medial collateral ligament; UCL, UEFA (Union of European Football Associations) Champions league.
External risk factors for injury in men’s professional football

Pre-season training/seasonal distribution
Several studies have evaluated the seasonal distribution of football injuries. Some studies found no differences in injury rate throughout the football season (Bjørneboe et al., 2014; Dauty et al., 2011; Lundblad et al., 2013; Waldén et al., 2013), while others found an increased injury rate during the pre-season compared to the competitive season, especially for training injury (Waldén et al., 2004), stress fracture (Ekstrand and Torstveit, 2012), fifth metatarsal fracture (Ekstrand and van Dijk, 2013), patellar tendinopathy (Hägglund et al., 2011), hamstring muscle injury (Petersen et al., 2010), overuse injury (Waldén et al., 2004) and re-injury (Waldén et al., 2004). In contrast, the injury rate for hamstring muscle injury has been found to be increased during competitive season compared to the pre-season (Hägglund et al., 2013a). Morgan and Oberlander studied injury rate in the American league and found that the late phase of the season yielded the greatest number of injuries. However, in this study exposure was not recorded (Morgan and Oberlander, 2001).

Match associated variables
Various match-related variables have been found to affect the injury rate within the match. Regarding match location, previous studies have found a lower injury rate in matches played away compared to home matches (Bengtsson et al., 2013b). This has specifically been found for hamstring and adductor muscle injuries (Hägglund et al., 2013a). In contrast, Nilsson et al. found a higher rate for head/neck injuries at away matches compared to matches played at home venue (Nilsson et al., 2013). The type of match played has also been found to affect injury rate. For example, the rate of moderate and severe injuries increased with the importance of the match (Bengtsson et al., 2013b). Regarding injury pattern, the high profile UCL matches have been associated with an increase in calf injuries and a decrease in quadriceps injuries (Hägglund et al., 2013a). The injury rate has also been found to vary during the match with trends towards an increased injury rate in the end of the first and second halves (Aoki et al., 2012; Lundblad et al., 2013; Waldén et al., 2013). In the FIFA World Cup, the injury rate is increased within the five minutes following a potential game disturbing incidents such as red/yellow card, goal and injury (Ryynänen et al., 2013b). Lastly, foul play has also been associated with an increased injury rate (Chomiak et al., 2000; Lundblad et al., 2013; Ryynänen et al., 2013a).
High match and training load

Dauty et al. found no association between the number of matches played each season in a French football club and injury rate (Dauty et al., 2011). However, Dupont et al. studied injury rate in a Scottish football club and found that playing two matches per week was associated with an increased injury rate (Dupont et al., 2010). Similarly, in the UCL setting Bengtsson et al. found that fixture congestion was associated with increased rates if muscle injuries (Bengtsson et al., 2013a). In a cohort of European football clubs, high total seasonal football exposure was identified as a risk factor for patellar tendinopathy (Hägglund et al., 2011). In contrast, data from the FIFA World Cup present a linear relationship between an increasing number of recovery days between matches and a higher injury rate (Ryynänen et al., 2013c). However, in this study no significant differences were found in the actual injury rates between the different days of recovery. Also, analyses were not adjusted for the type of match played even though the number of recovery days is typically higher before the semi-final and final matches compared to group-phase matches, and studies have showed that the injury rates increase with the importance of the match (Bengtsson et al., 2013b).

Weather and playing field conditions

In Czech football, about a fifth of players cited poor pitch quality as a causative factor for their injury (Chomiak et al., 2000). Studies in Japanese football found rainy weather to be associated with reduced injury rate (Aoki et al., 2012).

Team success

Eirale et al. evaluated the relationship between seasonal injury rate and team success in Qatar first-division football and found that lower injury rate was strongly correlated with team ranking position, more games won, more goals scored, greater goal difference and total points (Eirale et al., 2012). Likewise, in the UCL setting, Hägglund et al. found that lower injury rate was associated with increased points per league match (Hägglund et al., 2013b). In contrast, Dauty et al. studied the relation between national championships rank and injury rate in a single French professional football club, but found no significant association (Dauty et al., 2011). Regarding injury rates in relation to match results, Bengtsson et al. found a higher injury rate in matches resulting in a loss or a draw compared to a win (Bengtsson et al., 2013b). In contrast, Ryynänen recently found that players in a winning team have an increased injury rate compared to players in a drawing or losing team (Ryynänen et al., 2013b). However, when evaluating the association between team success and injury rates, the aspect of causality needs to be considered.
### Table 2. Studies evaluating external risk factors for football injury in men’s professional football after the year 2000

<table>
<thead>
<tr>
<th>Publication</th>
<th>Data collected</th>
<th>Setting</th>
<th>Risk factor studied</th>
<th>Injury type studied</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aoki et al., 2012</td>
<td>1993-2007</td>
<td>Japanese first league</td>
<td>Weather, time during match</td>
<td>Acute match time-loss injury &gt; 7 days</td>
</tr>
<tr>
<td>Bengtsson et al., 2013a</td>
<td>2001-2012</td>
<td>UCL</td>
<td>Recovery time between matches</td>
<td>Time-loss, muscle and ligament injury</td>
</tr>
<tr>
<td>Bengtsson et al., 2013b</td>
<td>2001-2010</td>
<td>UCL</td>
<td>Match result, venue, type of competition</td>
<td>Match time-loss injury</td>
</tr>
<tr>
<td>Chomiak et al., 2000</td>
<td>Not presented</td>
<td>Czech players amateur to professional</td>
<td>Training overload, playing field conditions, equipment, foul play</td>
<td>Severe injury</td>
</tr>
<tr>
<td>Daute et al., 2011</td>
<td>1995-2010</td>
<td>One professional French club</td>
<td>Matches/season, club ranking, seasonal distribution</td>
<td>Time-loss injury &gt; 72 hours</td>
</tr>
<tr>
<td>Dupont et al., 2010</td>
<td>2007-2009</td>
<td>One professional Scottish club</td>
<td>Match frequency</td>
<td>Time-loss injury</td>
</tr>
<tr>
<td>Eirale et al., 2012</td>
<td>2008-2009</td>
<td>Qatar first division</td>
<td>Team success</td>
<td>Time-loss injury</td>
</tr>
<tr>
<td>Ekstrand and Torstveit, 2012</td>
<td>2001-2009</td>
<td>European clubs</td>
<td>Pre-season exposure</td>
<td>Stress fracture</td>
</tr>
<tr>
<td>Ekstrand and van Dijk, 2013</td>
<td>2001-2012</td>
<td>UCL</td>
<td>Pre-season exposure</td>
<td>Fifth metatarsal fracture</td>
</tr>
<tr>
<td>Gajhede et al., 2013</td>
<td>2001-2012</td>
<td>UCL</td>
<td>Short rehab period</td>
<td>Time-loss Achilles tendon injury</td>
</tr>
<tr>
<td>Häggland et al., 2011</td>
<td>2001-2009</td>
<td>European clubs</td>
<td>Exposure load, team home surface, and seasonal distribution</td>
<td>Time-loss patellar tendinopathy</td>
</tr>
<tr>
<td>Häggland et al., 2013a</td>
<td>2001-2010</td>
<td>UCL</td>
<td>Type of match, match venue, period of season, climate region</td>
<td>Time-loss muscle injury</td>
</tr>
<tr>
<td>Häggland et al., 2013b</td>
<td>2001-2012</td>
<td>UCL</td>
<td>Team performance</td>
<td>Time-loss injury</td>
</tr>
<tr>
<td>Lundblad et al., 2013</td>
<td>2001-2012</td>
<td>UCL</td>
<td>Seasonal trend and distribution, time during match, foul play</td>
<td>Time-loss MCL injury of the knee</td>
</tr>
<tr>
<td>Morgan and Oberlander, 2001</td>
<td>1996</td>
<td>American first league</td>
<td>Seasonal distribution</td>
<td>Time-loss injury</td>
</tr>
<tr>
<td>Nilsson et al., 2013</td>
<td>2001-2010</td>
<td>UCL</td>
<td>Match result, venue, type of competition</td>
<td>Time-loss head/neck injury</td>
</tr>
<tr>
<td>Petersen et al., 2010</td>
<td>2007-2008</td>
<td>Danish first and second league</td>
<td>Seasonal distribution</td>
<td>Any physical complaint hamstring injury</td>
</tr>
<tr>
<td>Ryynänen et al., 2013a</td>
<td>2002, 2006, 2010</td>
<td>FIFA World Cup</td>
<td>Foul play</td>
<td>Medical attention injury</td>
</tr>
<tr>
<td>Ryynänen et al., 2013b</td>
<td>2002, 2006, 2010</td>
<td>FIFA World Cup</td>
<td>Game-disrupting incidents (red/yellow cards, goals, injuries)</td>
<td>Medical attention injury</td>
</tr>
<tr>
<td>Ryynänen et al., 2013c</td>
<td>2002, 2006, 2010</td>
<td>FIFA World Cup</td>
<td>Changes in the score, playing positions, recovery time</td>
<td>Medical attention injury</td>
</tr>
<tr>
<td>Waldén et al., 2005</td>
<td>2001</td>
<td>Swedish first league</td>
<td>Seasonal distribution</td>
<td>Time-loss and tissue injury</td>
</tr>
<tr>
<td>Waldén et al., 2013</td>
<td>2001-2012</td>
<td>UCL</td>
<td>Seasonal trend and distribution, time during match</td>
<td>Time-loss ankle injury</td>
</tr>
</tbody>
</table>

MCL, medial collateral ligament; FIFA, International Federation of Association Football; UCL, UEFA (Union of European Football Associations) Champions League.
Artificial turf and injury rates in football

Artificial turf (AT), introduced in football in the late 1960s (first-generation) and late 1980s (second-generation), respectively, were both associated with a higher injury rate compared to natural grass (NG). These turfs also had a different injury pattern compared to play on NG, with higher proportions of abrasions and ankle injuries (Árnason et al., 1996, Engebretsen et al., 1987). Today third-generation of AT are available, characterised by grass-like fibres that are longer (50-60 mm) and more spread than earlier generations’, and are in-filled with sand and rubber granules (Dragoo et al., 2010). These turfs, when quality approved by FIFA, are sometimes named football turfs and can today function as the surface for football at all levels, including professional football (FIFA, 2012).

Injury rate on AT vs. NG - critical review and evidence grading

For the background section of my thesis, I performed a critical review comparing injury rates on AT and NG, at different levels of football play (unpublished data). Two inclusion criteria were used: 1) articles presenting comparisons of injury rates on AT compared to NG, or comparisons for injury rates of clubs mostly playing on AT compared to clubs mostly playing on NG, and, 2) the study setting was set to male or female football at any level. A literature search was performed in the PubMed database on October 13, 2014. The search term used was “artificial turf” and this yielded an initial search result of 124 articles. The titles and abstracts of these articles were reviewed for inclusion, and finally 10 articles were included for critical review. The electronic database search was supplemented by hand searching the reference lists of included articles to identify any further articles to be included in the review. No additional articles were identified by the hand search. Out of the 10 articles, four studied professional football, three studied amateur football and three studied adolescent football (Table 3). All included studies had an observational design. A quality assessment was performed (Table 4) using the GRADE statement (Grade Working Group, 2004).
Table 3. Articles presenting injury rates at artificial turf compared to grass in football, separated by activity level and quality graded according to GRADE

<table>
<thead>
<tr>
<th>Professional</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex</td>
<td>Setting</td>
<td>Injuries (n)</td>
<td>Players (n)</td>
<td>RR training (CI)⁠¹</td>
<td>RR match (CI)²</td>
<td>Injury pattern¹</td>
<td>Quality²</td>
</tr>
<tr>
<td>M</td>
<td>Saudi national team</td>
<td>154</td>
<td>49</td>
<td>Non-significant³</td>
<td>Non-significant³</td>
<td>-</td>
<td>Very low</td>
</tr>
<tr>
<td>M+F</td>
<td>Various European clubs</td>
<td>2105</td>
<td>767</td>
<td>1.0 (0.8 - 1.2)</td>
<td>1.0 (0.9-1.2)</td>
<td>Higher rate for ankle sprain</td>
<td>Moderate</td>
</tr>
<tr>
<td>M</td>
<td>Norwegian clubs</td>
<td>1067</td>
<td>Unclear</td>
<td>1.07 (0.87-1.32)</td>
<td>1.04 (0.86-1.25)</td>
<td>Non-significant differences</td>
<td>Low</td>
</tr>
<tr>
<td>M</td>
<td>Various European clubs</td>
<td>775</td>
<td>290</td>
<td>0.82 (0.60-1.13)</td>
<td>0.91 (0.72-1.16)</td>
<td>Higher rate for ankle injury</td>
<td>Low</td>
</tr>
<tr>
<td>M</td>
<td>Saudi national team</td>
<td>154</td>
<td>49</td>
<td>Non-significant³</td>
<td>Non-significant³</td>
<td>-</td>
<td>Very low</td>
</tr>
<tr>
<td>M+F</td>
<td>Various European clubs</td>
<td>2105</td>
<td>767</td>
<td>1.0 (0.8 - 1.2)</td>
<td>1.0 (0.9-1.2)</td>
<td>Higher rate for ankle sprain</td>
<td>Moderate</td>
</tr>
<tr>
<td>M</td>
<td>Norwegian clubs</td>
<td>1067</td>
<td>Unclear</td>
<td>1.07 (0.87-1.32)</td>
<td>1.04 (0.86-1.25)</td>
<td>Non-significant differences</td>
<td>Low</td>
</tr>
<tr>
<td>M</td>
<td>Various European clubs</td>
<td>775</td>
<td>290</td>
<td>0.82 (0.60-1.13)</td>
<td>0.91 (0.72-1.16)</td>
<td>Higher rate for ankle injury</td>
<td>Low</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Amateur</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>M</td>
<td>American collegiate</td>
<td>693</td>
<td>Unclear</td>
<td>-</td>
<td>0.81 p&lt;0.001⁴</td>
<td>-</td>
<td>Very low</td>
</tr>
<tr>
<td>M+F</td>
<td>American collegiate</td>
<td>1794</td>
<td>Unclear</td>
<td>-</td>
<td>M: 1.06 (0.80-1.42)</td>
<td>F: 0.88 (0.73-1.05)</td>
<td>M: Higher rate for head/neck injury and laceration</td>
</tr>
<tr>
<td>M+F</td>
<td>American collegiate</td>
<td>1592</td>
<td>Unclear</td>
<td>M: 1.11 (0.94-1.31)</td>
<td>-</td>
<td>M: Higher rate for ankle injury, foot injury, sprain</td>
<td>Low</td>
</tr>
<tr>
<td>M+F</td>
<td>American collegiate</td>
<td>1592</td>
<td>Unclear</td>
<td>F: 0.93 (0.77-1.13)</td>
<td>-</td>
<td>F: Lower rate for lower extremity sprain</td>
<td>Low</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Adolescent</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>M+F</td>
<td>Norway Cup</td>
<td>2454</td>
<td>&gt; 60,000</td>
<td>-</td>
<td>OR 1.05 (0.68-1.61)⁵</td>
<td>Higher rate for back/spine and shoulder/clavicle</td>
<td>Low</td>
</tr>
<tr>
<td>M</td>
<td>Japanese U-17</td>
<td>657</td>
<td>301</td>
<td>1.18 (0.97-1.43)</td>
<td>1.02 (0.58-1.79)</td>
<td>-</td>
<td>Lower rate for ankle injury</td>
</tr>
<tr>
<td>F</td>
<td>Norwegian U-17</td>
<td>456</td>
<td>2020</td>
<td>1.0 (0.6-1.5)</td>
<td>1.0 (0.8-1.3)</td>
<td>Higher rate for severe injury</td>
<td>Low</td>
</tr>
</tbody>
</table>

CI, confidence intervals (all are 95% CI except Ekstrand et al., 2011a, which is 99% CI); F, Female; M, Male; RR, rate ratio for acute injury rate; GRADE, Grades of recommendation, assessment, development and evaluation. ¹Grass used as the reference. ²Based on result from Table 3 (unpublished results). ³Only descriptive date presented for main outcome variable. ⁴Acute and overuse injuries included. ⁵Odds ratio, adjusted for sex and age.
Table 4. Assessment of study quality in articles presenting injury rates at artificial turf compared to grass in football, separated by activity level

<table>
<thead>
<tr>
<th>Study period &gt; 1 season</th>
<th>Sufficient power primary outcome</th>
<th>Sufficient power injury pattern</th>
<th>Separates different types of AT</th>
<th>Follow consensus statement</th>
<th>Separates acute/overuse injuries</th>
<th>Separates training/match IR</th>
<th>Reporting number of players</th>
<th>Registered number of players</th>
<th>Declared conflicting interest</th>
<th>Adjustments for multiple comparisons</th>
<th>Quality points</th>
<th>Assessment quality</th>
<th>Quality of evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Professional</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alnuttawa et al., 2014</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes (TBE)</td>
<td>No</td>
<td>Not relevant</td>
<td></td>
<td></td>
<td>5 / 10</td>
<td>Degraded one step</td>
<td>Very low</td>
</tr>
<tr>
<td>Ekstrand et al., 2011a</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes (IBE)</td>
<td>No</td>
<td>Yes</td>
<td></td>
<td></td>
<td>9 / 11</td>
<td>Promoted one step</td>
<td>Moderate</td>
</tr>
<tr>
<td>Bjørneboe et al., 2010</td>
<td>Yes</td>
<td>Not presented</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes (TBE)</td>
<td>No</td>
<td>No</td>
<td></td>
<td></td>
<td>6 / 11</td>
<td>Low</td>
<td></td>
</tr>
<tr>
<td>Ekstrand et al., 2006</td>
<td>Yes</td>
<td>Not presented</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes (IBE)</td>
<td>No</td>
<td>No</td>
<td></td>
<td></td>
<td>7 / 11</td>
<td>Low</td>
<td></td>
</tr>
<tr>
<td>Amateur</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Meyers et al., 2013</td>
<td>Yes</td>
<td>Not presented</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes (TBE)</td>
<td>No</td>
<td>No</td>
<td></td>
<td></td>
<td>3 / 11</td>
<td>Degraded one step</td>
<td>Very low</td>
</tr>
<tr>
<td>Fuller et. al., 2007a</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes (TBE)</td>
<td>No</td>
<td>No</td>
<td></td>
<td></td>
<td>7 / 11</td>
<td>Low</td>
<td></td>
</tr>
<tr>
<td>Fuller et. al., 2007b</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes (TBE)</td>
<td>No</td>
<td>No</td>
<td></td>
<td></td>
<td>7 / 11</td>
<td>Low</td>
<td></td>
</tr>
<tr>
<td>Adolescent</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soligard et al., 2012</td>
<td>Yes</td>
<td>Not presented</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes (TBE)</td>
<td>No</td>
<td>No</td>
<td></td>
<td></td>
<td>6 / 11</td>
<td>Low</td>
<td></td>
</tr>
<tr>
<td>Aoki et al., 2010</td>
<td>No</td>
<td>Not presented</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes (IBE)</td>
<td>No</td>
<td>Not relevant</td>
<td></td>
<td></td>
<td>5 / 10</td>
<td>Low</td>
<td></td>
</tr>
<tr>
<td>Steffen et al., 2007</td>
<td>No</td>
<td>Not presented</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes (TBE)</td>
<td>No</td>
<td>No</td>
<td></td>
<td></td>
<td>6 / 11</td>
<td>Low</td>
<td></td>
</tr>
</tbody>
</table>

AT, artificial turf; IBE, individual based exposure; IR, injury rate (injuries/1000 hours exposure); TBE, team based exposure. 1 Only descriptive analyses performed. 2 Sufficient sample for male players but not female players. 3 P-value set to p<0.01. 4 Sample sufficient according to power calculation in Ekstrand et al., 201 la. 5 Sample in-sufficient according to power calculation in Ekstrand et al., 201 la. 6 Only match injuries registered. 7 Only training injuries registered.
Professional football

The first paper comparing injury rates on third-generation AT with injury rates on NG surfaces was initiated by UEFA. All professional football clubs in Europe with AT installed at their home stadium were invited to participate in a prospective cohort study. Data collection started in 2003 and the first paper based on this cohort included data until November 2005 (Ekstrand et al., 2006). This study used the time-loss definition for injury, collected acute and overuse injuries from all club training sessions and matches and collected exposure using IBE. The first paper included data on male players only, and showed no difference in the overall acute injury rate in matches or training sessions between AT and NG. However, an increased rate of ankle injuries was found on AT (Ekstrand et al., 2006). When additional data collected up to October 2008 were analysed, it was also found that there was no difference in injury rates between the two surface types among female elite players (Ekstrand et al., 2011a). Regarding injury patterns, male players had a higher rate of ankle injuries again, and this study also showed a decreased rate for muscle injuries on AT. No between-surface differences were found in injury patterns for female players (Ekstrand et al., 2011a), although this may be due to a relative power loss in the female sub-cohort.

In 2010, Bjørneboe and colleagues published a prospective cohort study based on data from the male Norwegian first league from season 2004 to 2007 (Bjørneboe et al., 2010). This is a well-powered study with a long follow-up period. However, it is limited by the lack of detailed registration of exposure by using TBE. Also, the total number of players participating is not reported, suggesting a potential threat to internal validity. Furthermore no adjustments were made for multiple comparisons even though injury pattern was evaluated. The findings of this study confirmed the previous finding of no difference in injury rate between the two surfaces. In contrast, no significant differences in injury patterns were identified in that study.

Almatuwa and colleagues recently published a pilot study, studying the Saudi male national team playing a tournament on AT (December 2010) compared to another tournament played on NG (January 2011) (Almatuwa et al., 2014). The main limitation of this study was the small sample size. With a medical attention definition of injury, 154 injuries were registered. Time-loss injuries from this material only generated a total number of 32 match injuries and 20 training injuries and, therefore, only descriptive data are presented.
Amateur football

In amateur football, Fuller and colleagues published the first comparative studies of injury rates across third-generation AT and NG surfaces in 2007 (Fuller et al., 2007a, Fuller et al., 2007b). These papers were based on the same prospective cohort of female and male American collegiate players followed in 2005 to 2006. Injury rates in matches (Fuller et al., 2007a) and in training (Fuller et al., 2007b) were evaluated and more than 3000 injuries were included. However it is limited by the use of TBE, no report of the total number of players participating, and the lack of adjustments for multiple comparisons. There were no differences in general acute injury rates on AT compared to NG. In match play, male players had an increased injury rate for head/neck injuries and lacerations on AT. In training, male players had an increased rate for ankle injuries, foot injuries and sprains on AT, while female players had a decreased rate for lower extremity sprains on AT.

In 2013, Meyers published a prospective cohort study of match injuries in female collegiate football between season 2007 and 2011 (Meyers, 2013). This in the only study so far that has detected a significant difference in total acute injury rate on AT compared to NG; presenting a 20% decrease in match injury rate on AT. However, this study did not follow the consensus statement regarding study methodology in football injury studies (Fuller et al., 2006), which complicates comparisons to previous literature. No exact exposure was registered; and injury rate was defined as injuries / 10 matches. The study also assessed many risk factors for injury including cleat design and weather at injury occurrence. However, no data were presented for the exposure to these risk factors. Importantly, this is also the only published study declaring an AT company as a funding source. These relations with the industry, together with results that are in contrast to all other published literature may call into question the validity of the results (Orchard, 2013).

Adolescent football

In 2007, Steffen and colleagues published the first study in the setting of young players (Steffen et al., 2007). They prospectively followed female players from the Norwegian U-17 league in the 2005 season, and recorded 456 injuries. Acute injuries were collected and exposure registered with TBE. No differences were found in acute injury rates on AT compared to NG in either training or matches. However, there was an increased rate of severe injuries on AT.
Aoki and colleagues studied 12 to 17 years old Japanese players from six teams that typically trained on either AT or NG (Aoki et al., 2010). They compared the AT clubs and the NG clubs without finding any differences in the total injury rate. However, the players predominantly playing on AT had a higher rate of back pain during training.

In 2012, Soligard and colleagues published a prospective cohort study based on material from the Norway Cup one of the world’s largest yearly youth tournaments (Soligard et al., 2012). Data from over 60 000 players were collected using a medical attention definition of injury for match injuries, reported by the club coaches after each match. No differences were found in the total acute injury rate on AT compared to NG. Regarding injury pattern in this setting, a decreased rate was found for ankle injuries on AT; and a higher rate of back/spine and shoulder/clavicular injuries were found on AT. The finding of a decreased injury rate for ankle injuries on AT, was in contrast to the increased rate found in professional football, and may be due to the difference in quality of grass pitches between youth and professional level football. Even though this study included about 60 000 players at four consecutive tournaments, the main methodological limitation is the insufficient sample size. Due to a low general injury rate and since only 10% of matches were played on NG, only 206 medical attention injuries and 25 time-loss injuries were registered on NG. Therefore, sub-analyses of injury patterns in this study are likely affected by a risk for type II errors.

Overuse injuries and AT
Most previous studies have only compared acute injury rates between the AT and NG playing surfaces (Bjørneboe et al., 2010; Fuller et. al., 2007a; Fuller et. al., 2007b; Soligard et al., 2012; Steffen et al., 2007) and knowledge about the influence of AT exposure on overuse injuries in professional football is limited (Williams et al., 2011). Only one previous study in elite football has included a control group consisting of clubs playing their home matches on NG (Ekstrand et al., 2006). However, the limited sample in that study did not allow for detailed analysis of potential variations in injury rates between clubs with AT at their home venue and those with NG.

Surface shifts and play on unaccustomed surfaces
Owing to different surfaces at teams’ home venues, surface shifts frequently occur in Swedish and Norwegian football. Frequent surface shifts has been proposed as a risk factor for football injury (Ekstrand and Nigg, 1989), but this has never been directly evaluated. It is also possible
that the injury rate on different surfaces could vary depending if the player is accustomed to playing on that specific surface or not.

**Climate at club home venue**

Regional differences in injury rates have been detected in female amateur football where clubs from the northern (colder) part of Sweden had higher injury rates compared to southern (warmer) clubs (Jacobson and Tegner, 2006). Similarly, when climate categorisation was based on a strict classification using the Köppen–Geiger system (Kottek et al., 2006), male professional football clubs from northern parts of Europe had higher injury rates compared to clubs from southern Europe with a Mediterranean climate (Waldén et al., 2013). Clubs could chose to install AT on their home venue due to their mastery climate, but no study has evaluated if there are differences in injury rate between different climate zones in Scandinavian male professional football.

Therefore, there is a rationale for further study of the relation between surface types, differences in climate at club home venue, shifts between surfaces and overuse injuries.
AIMS OF THE THESIS

The overall aim of this thesis was to investigate potential internal and external risk factors for injury in male professional football, with a focus on time spent in professional football, player age, playing position, playing surface, changes between surfaces, and climate; and to evaluate the study methodology.

The specific aims of this thesis were:

- to investigate whether being a newcomer in professional football influences injury rates (Paper I).
- to evaluate if player age and playing position influence injury rates (Paper I).
- to compare acute injury rates in professional football played on AT and NG at the individual player level (Paper II).
- to compare, at club level, acute and overuse injury rates between clubs that have AT at their home venue and clubs that have NG (Paper II).
- to investigate the influence of frequent surface shifts, and from playing matches on an unaccustomed surface, on overuse injury risk (Paper III).
- to evaluate if match play on unaccustomed surface influences injury rates during that particular match (Paper III).
- to evaluate if injury rates differ between clubs from different climate zones (Paper III).
- to compare the inter-rater agreement in injury capture rate and injury categorisation using individual based exposure and team based exposure when studying the same professional football clubs (Paper IV).
METHODS

Study design
All four papers in this thesis followed the same general methodology. The study design has previously been validated and implemented on a professional level in studies of the Swedish and Danish first leagues, UCL, and European Championships (Hägglund et. al., 2005).

Clubs were followed prospectively during full football seasons (pre-season and competitive season). All players with a first team contract were invited to participate. If a player was injured at study inclusion the present injury was not taken into account. Players who left the club before the end of a season were included for as long as they participated in the study.

Data collection
A representative from each club’s medical team functioned as a contact person between the club and the study group. The contact person was responsible for informing players about the study aim and procedures as well as reporting injury and exposure data to the study group. Participation in all training sessions and matches was registered on an individual basis in minutes for training sessions and matches separately. Exposure and injury forms were sent to the study group on a monthly basis and were checked for completeness. Prompt feedback was sent to club contact persons in order to correct any missing or unclear data, if necessary.

Study forms
Three standardised forms were used for data collection. A baseline form was used to collect the individual player characteristics: age, height, body mass, dominant leg (preferred kicking leg), playing position and previous severe injuries and surgeries (Appendix 1). The exposure form included all club and national team training and match exposures in minutes. In Papers II to IV, exposures were also separated into specific playing surface at activity (NG, AT, other surface), (Appendices 2a, 2b and 2c). The injury form contained information about injury date, injury type, injury location, injury mechanism, and playing activity, and for Papers II to IV, the surface at injury occurrence (Appendix 3).

Definitions

Injury data
Injury definitions used in this thesis follow the consensus statement established for studying football injuries (Fuller et al., 2006). A time-loss injury definition was used, i.e. a physical complaint sustained during football training or match play leading to a player being unable to fully
participate in future training or match play. A player was regarded as injured until he was declared fit by the medical team to be able to fully participate in all types of training and be available for match selection. Injuries were divided into acute injuries (sudden onset and known cause), and overuse injuries (insidious onset and no known trauma). Injury severity was based on the number of days elapsed from injury to return to play, and was categorised as: slight (0 days), minimal (1-3 days), mild (4–7 days), moderate (8-28 days), and severe (> 28 days).

**Exposure data**

Two different methods for recording player exposure are recommended – IBE or TBE (Fuller et al., 2006). IBE include all players’ individual time of participation in each training session and match, whereas TBE registers a sum of exposure for each activity based on the number of players participating and the length of the activity (Fuller et al., 2006). IBE is used in Paper I-III. In Paper IV, a methodology paper, both methods are utilised. In all papers in this thesis, training session was defined as training with the first or reserve team of the club, or with a youth or senior national team. Only team training that involved physical activity under the supervision of coaching staff was included. Match play was defined as competitive or friendly match against another club, or national team matches.

**Paper-specific definitions**

In Paper I, players were categorised by the club contact person as goalkeeper, defender, midfielder or forward. Players were further categorised based on sextiles of age distribution within the cohort (≤ 21, 22-23, 24-26, 27-28, 29-30 and ≥ 31 years). These age categories were chosen to identify different cut off values used in previous studies (Árnason et al., 2004a, Hägglund et al., 2006), as well as to analyse injury patterns related to age in more detail. A newcomer to professional football was defined as a player undergoing his first season with a first-team contract after being promoted from a club youth academy. All other players were regarded as established players. In Paper II and Paper III, clubs were defined as an AT club or NG club according to the surface installed at their home venue. In Paper III, accustomed surface was defined as the surface (AT or NG) each club had installed at their home venue, and the other surface was defined as unaccustomed surface for that club.
Setting and participants

**Paper I**
Data included 26 clubs from 10 countries (Belgium, The Netherland, England, France, Germany, Italy, Portugal, Scotland, Spain and Ukraine), in the so-called UCL Injury Study. Clubs were followed for a varying number of seasons between 2001/02 and 2009/10, Table 5. In total, 1401 players with a mean age of 25.8 ± 4.5 years were included in the study, followed over 3207 player seasons. There were 140 goalkeepers (10%), 433 defenders (31%), 514 midfielders (37%), and 314 forwards (22%).

**Paper II**
All clubs in the male first leagues in Norway (Tippeligaen) and Sweden (Allsvenskan) were invited to participate in the study, named the Nordic Football Injury Audit (NFIA). Clubs were followed prospectively for two consecutive seasons, 2010 and 2011, including pre-season (January to late March) and competitive season (late March to late October or early November). In 2010, 12 of 16 Norwegian and 14 of 16 Swedish clubs participated in the study. In 2011, the participation was 14 of 16 and 15 of 16 clubs, respectively (Table 6). Among the 32 clubs that entered the study, eight players from two clubs declined to participate. In total, 496 players from AT clubs, and 1011 players from NG clubs, were included in the analyses. All AT surfaces in this study held the FIFA recommended two star licence (FIFA, 2012). Further details about the AT surfaces included in this study are presented in Table 6.

**Paper III**
This study was based on the same cohort as Paper II. To study the injury characteristics of players that mainly participate in club first team matches, inclusion in Paper III was restricted to players with exposure from at least five first team matches per season. This resulted in inclusion of 1,507 player seasons, 703 during season 2010 and 804 during season 2011.

**Paper IV**
This study was a post-hoc analysis of prospectively collected data from two injury audits studying the same two Norwegian male professional football clubs (Club A and Club B) over two consecutive seasons (2008-2009). Data registration in both audits was carried out by the same club physiotherapists (one in each club), who attended all club training sessions and matches, and sent separate injury and exposure reports to each injury audit on monthly basis.
Between 2004 and 2009, the Football Research Group (FRG) from Linköping, Sweden, conducted an injury audit that included 25 European professional clubs playing their home matches on artificial turf (Ekstrand et al., 2011b). The FRG audit collected exposure by IBE and is further referred to in this thesis as the IBE audit. The Oslo Sports Trauma Research Center (OSTRC) has carried out a domestic injury audit of the male top division in Norway since 2000 (Andersen et al., 2004). The OSTRC audit used the TBE approach to register player exposure and is further referred to in this thesis as the TBE audit.
Table 5. Clubs included in *Paper I*

<table>
<thead>
<tr>
<th></th>
<th>01/02</th>
<th>02/03</th>
<th>03/04</th>
<th>04/05</th>
<th>05/06</th>
<th>06/07</th>
<th>07/08</th>
<th>08/09</th>
<th>09/10</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Scotland (Scottish Premier League)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rangers FC</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>England (Premier League)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arsenal FC</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Chelsea FC</td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Liverpool FC</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td>X¹</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Manchester United FC</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Newcastle United FC</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td><strong>France (Ligue 1)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RC Lens</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Paris St Germain FC</td>
<td>X</td>
<td>X</td>
<td>X¹</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stade Rennais FC</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Olympique Lyonnais</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td><strong>The Netherlands (Eredivisie)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AFC Ajax</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>PSV Eindhoven</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td><strong>Belgium (Jupiler Pro League)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RSC Anderlecht</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Club Brugge KV</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Germany (1. Bundesliga)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BVB Dortmund</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Hamburger SV</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>FC Bayern München</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td><strong>Italy (Serie A)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AC Milan</td>
<td>X</td>
<td>X</td>
<td>X¹</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X¹</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>FC Inter</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Juventus FC</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AFC Fiorentina</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td><strong>Portugal (Liga Sagres)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SL Benfica</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>FC Porto</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td><strong>Spain (Primera División)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FC Barcelona</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Real Madrid CF</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td><strong>Ukraine (Ukrainian Premier League)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FC Shakhtar Donetsk</td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

¹Injury and exposure data recorded for approximately half season only.
Table 6. Clubs included in *Paper II* and *Paper III*

<table>
<thead>
<tr>
<th>Country</th>
<th>Team</th>
<th>Location</th>
<th>Climate zone</th>
<th>Surface at home arena</th>
<th>Producer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Norway</td>
<td>Sarpsborg 08 FF</td>
<td>Sarpsborg</td>
<td>Warm temperate climate</td>
<td>Artificial turf</td>
<td>Fieldturf</td>
</tr>
<tr>
<td>Norway</td>
<td>SK Brann</td>
<td>Bergen</td>
<td>Warm temperate climate</td>
<td>Grass</td>
<td>-</td>
</tr>
<tr>
<td>Norway</td>
<td>FK Haugesund¹</td>
<td>Haugesund</td>
<td>Warm temperate climate</td>
<td>Grass</td>
<td>-</td>
</tr>
<tr>
<td>Norway</td>
<td>IK Start</td>
<td>Kristiansand</td>
<td>Warm temperate climate</td>
<td>Grass</td>
<td>-</td>
</tr>
<tr>
<td>Norway</td>
<td>Viking FK</td>
<td>Stavanger</td>
<td>Warm temperate climate</td>
<td>Grass</td>
<td>-</td>
</tr>
<tr>
<td>Norway</td>
<td>Sogndal IL²</td>
<td>Sogndal</td>
<td>Warm temperate climate</td>
<td>Grass</td>
<td>-</td>
</tr>
<tr>
<td>Norway</td>
<td>Aalesunds FK</td>
<td>Aalesund</td>
<td>Warm temperate climate</td>
<td>Artificial turf</td>
<td>Greenfields</td>
</tr>
<tr>
<td>Norway</td>
<td>Molde FK³</td>
<td>Molde</td>
<td>Warm temperate climate</td>
<td>Grass</td>
<td>-</td>
</tr>
<tr>
<td>Norway</td>
<td>Rosenborg BK</td>
<td>Trondheim</td>
<td>Warm temperate climate</td>
<td>Grass</td>
<td>-</td>
</tr>
<tr>
<td>Norway</td>
<td>Odd Grenland BK²</td>
<td>Skien</td>
<td>Snow climate</td>
<td>Artificial turf</td>
<td>Fieldturf</td>
</tr>
<tr>
<td>Norway</td>
<td>Stabæk IF</td>
<td>Bærum</td>
<td>Snow climate</td>
<td>Artificial turf</td>
<td>Fieldturf</td>
</tr>
<tr>
<td>Norway</td>
<td>Strømsgodset Drammen</td>
<td>Drammen</td>
<td>Snow climate</td>
<td>Artificial turf</td>
<td>Saltex</td>
</tr>
<tr>
<td>Norway</td>
<td>Lillesund SK</td>
<td>Lillesund</td>
<td>Snow climate</td>
<td>Grass</td>
<td>-</td>
</tr>
<tr>
<td>Norway</td>
<td>Vålerenga IF</td>
<td>Oslo</td>
<td>Snow climate</td>
<td>Grass</td>
<td>-</td>
</tr>
<tr>
<td>Norway</td>
<td>Hønefoss BK</td>
<td>Hønefoss</td>
<td>Snow climate</td>
<td>Artificial turf</td>
<td>Fieldturf</td>
</tr>
<tr>
<td>Norway</td>
<td>Tromsø IL</td>
<td>Tromsø</td>
<td>Snow climate</td>
<td>Artificial turf</td>
<td>Fieldturf</td>
</tr>
<tr>
<td>Sweden</td>
<td>IF Elfsborg</td>
<td>Borås</td>
<td>Warm temperate climate</td>
<td>Artificial turf</td>
<td>Fieldturf</td>
</tr>
<tr>
<td>Sweden</td>
<td>IFK Göteborg</td>
<td>Göteborg</td>
<td>Warm temperate climate</td>
<td>Grass</td>
<td>-</td>
</tr>
<tr>
<td>Sweden</td>
<td>Helsingborgs IF</td>
<td>Helsingborg</td>
<td>Warm temperate climate</td>
<td>Grass</td>
<td>-</td>
</tr>
<tr>
<td>Sweden</td>
<td>Halmstads BK</td>
<td>Halmstad</td>
<td>Warm temperate climate</td>
<td>Grass</td>
<td>-</td>
</tr>
<tr>
<td>Sweden</td>
<td>Malmö FF</td>
<td>Malmö</td>
<td>Warm temperate climate</td>
<td>Grass</td>
<td>-</td>
</tr>
<tr>
<td>Sweden</td>
<td>BK Häcken</td>
<td>Göteborg</td>
<td>Warm temperate climate</td>
<td>Grass</td>
<td>-</td>
</tr>
<tr>
<td>Sweden</td>
<td>Trelleborgs FF</td>
<td>Trelleborg</td>
<td>Warm temperate climate</td>
<td>Grass</td>
<td>-</td>
</tr>
<tr>
<td>Sweden</td>
<td>Kalmar FF</td>
<td>Kalmar</td>
<td>Warm temperate climate</td>
<td>Grass</td>
<td>-</td>
</tr>
<tr>
<td>Sweden</td>
<td>Mjällby AIF</td>
<td>Sölvesborg</td>
<td>Warm temperate climate</td>
<td>Grass</td>
<td>-</td>
</tr>
<tr>
<td>Sweden</td>
<td>GAIS</td>
<td>Göteborg</td>
<td>Warm temperate climate</td>
<td>Grass</td>
<td>-</td>
</tr>
<tr>
<td>Sweden</td>
<td>Örebro SK</td>
<td>Örebro</td>
<td>Snow climate</td>
<td>Artificial turf</td>
<td>Mondo</td>
</tr>
<tr>
<td>Sweden</td>
<td>Gefle IF</td>
<td>Gefle</td>
<td>Snow climate</td>
<td>Artificial turf</td>
<td>Saltex</td>
</tr>
<tr>
<td>Sweden</td>
<td>IFK Norrköping</td>
<td>Norrköping</td>
<td>Snow climate</td>
<td>Artificial turf</td>
<td>Polytan</td>
</tr>
<tr>
<td>Sweden</td>
<td>Djurgårdens IF</td>
<td>Stockholm</td>
<td>Snow climate</td>
<td>Grass</td>
<td>-</td>
</tr>
<tr>
<td>Sweden</td>
<td>AIK²</td>
<td>Solna</td>
<td>Snow climate</td>
<td>Grass</td>
<td>-</td>
</tr>
<tr>
<td>Sweden</td>
<td>Åtvidabergs FF³</td>
<td>Åtvidaberg</td>
<td>Snow climate</td>
<td>Grass/Artificial turf</td>
<td>Greenfields</td>
</tr>
</tbody>
</table>

Clubs are categorised into climate zones according to the Köppen-Geiger Climate Classification System (Kottek et al., 2006). ¹Club participated in season 2010 only. ²Club participated in season 2011 only. ³Club installed artificial turf during 2010 and was thereafter regarded as an artificial turf club.
DATA ANALYSIS AND STATISTICS

All statistical analyses were performed using IBM SPSS STATISTICS, versions 18-22. All analyses were two-sided. In Papers I, III and IV the alpha level was set to \( p < 0.05 \), while owing to the large number of comparisons that were made in Paper II, an alpha level of \( < 0.01 \) was used to decrease the risk of type I error. An overview of the statistical methods used is presented in Table 7.

Table 7. Statistical methods used within this thesis

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Descriptive statistics</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cumulative overuse incidence rate with 95% CI</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Injury rate with 95% CI</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Injury rate with 99% CI</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean values with standard deviation</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Analytic statistics</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ANOVA with Bonferroni post hoc test</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rate ratio, significance tested with ( z )-statistics</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>T-test</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Regression analysis</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cox proportional hazard regression</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Generalised estimating equations</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Agreement analysis</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cohen’s Kappa analysis</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Prevalence and Bias adjusted Kappa analysis</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>

ANOVA, analysis of variance; CI: confidence interval.

Anthropometrics and exposures

For quantitative, normally distributed variables (Paper I: player age, training hours, match hours; Paper II: player age, height, weight, training hours and match hours), mean values and standard deviations (SD) were calculated, and groups were compared by analysis of variance (ANOVA) with the Bonferroni post hoc test.
Injury rate

In all four papers, injury rate was expressed as the number of injuries/1000 exposure hours with 95% confidence interval (95% CI). Groups were compared using a rate ratio (RR) with 95% or 99% confidence interval (CI), and statistical significance was tested using z-statistics (Lindenfeld et al., 1994).

Injury rate on AT compared to NG

In Paper II, the injury rate in match play and training on AT was compared to NG. Due to the fact that pre-season football activities were largely carried out on AT, and due to the difficulty in attributing overuse injuries to a specific match or training session (and thus a specific surface), only acute injuries that occurred during the competitive season were included when comparing injury rates on AT and NG.

Injury rate for AT clubs compared to NG clubs

Overall injury rates were compared for AT clubs and NG clubs. In addition, separate analyses were made for differences in injury rate between AT clubs and NG clubs when playing on AT vs. NG, and for AT clubs vs. NG clubs in Sweden and in Norway.

Injury rate on accustomed compared to unaccustomed surfaces

In Paper III, analyses were made to compare injury rates on accustomed vs. unaccustomed surfaces, while controlling for match location. This was made by comparing injury rate at a) home matches (AT or NG), b) away matches on AT, and c) away matches on NG. Analyses were made for AT and NG clubs separately. Only the competitive part of each season was included.

Injury rate in clubs from different climate zones

In Paper III, the Köppen-Geiger Climate Classification System identifies five different general climate types, based on the average monthly temperature and precipitation (Kottek et al, 2006). Each main category is further divided into several subtypes by adding two lower case letters: the first letter denotes precipitation and the second letter denotes air temperature. In Scandinavia the dominating climate types are Cfb (warm temperate, fully humid, warm summer), Cfc (warm temperate, fully humid, cool summer), Dfb (snow climate, fully humid, warm summer) and Dfc (snow climate, fully humid, cool summer).

Clubs in Paper III were located in two of these general climate types: warm temperate climates (Cfb and Cfc) with a mean temperature from -3 to + 18 °C, and snow climates (Dfb
and Dfc) with a mean temperature of ≤ -3 °C. Injury rates were compared between clubs from the different climate zones, including both the pre-season and competitive season. Analyses were made including all clubs, and for AT clubs and NG clubs separately.

**Cumulative overuse incidence rate**
In *Paper II*, the cumulative incidence rate (CIR) was described for overuse injuries. The seasonal CIR was calculated as the number of players sustaining at least one new overuse injury each season/total number of players participating each season x 100. One club that changed surface in the middle of season 2010 was excluded from the CIR analyses. Mean seasonal CIRs for seasons 2010 and 2011 were compared between groups using a RR (with 95% CI) and significance was tested using z-statistics.

**Generalised estimating equations**
In *Paper III*, for analyses on the association between frequency of surface shifts, match play on accustomed vs. unaccustomed surface, and overuse injury risk, a generalised estimating equation (GEE) model with a binominal distribution and log link function was used. The GEE approach was used since it allowed assessment of potential club clustering effects and within-player variations, although none of these factors were found to significantly affect the outcome.

Each competition match on player individual level was used as an observation in the model. The outcome was any overuse injury occurring a maximum of three days after each match observation. First, potential associations between frequent surface shifts during five-match sequences and subsequent overuse injury risk was analysed. For each match observation, the number of surface shifts in the previous match sequence (four previous matches plus the match observation) was used as an independent variable. Players with exposure from at least four matches in the previous match sequence, and the match observation were included. Match frequency in the previous match sequence (days during sequence) and match location at match observation (home/away) were included as covariates. Second, the risk of overuse injury when playing matches on accustomed compared to unaccustomed surfaces was analysed. Players with any exposure at each match observation were included in the analysis. The GEE results were presented with risk ratios and 95% confidence intervals (CI).
Survival analysis

In Paper I, a Cox regression analysis was used to study the influence of potential risk factors on any time-loss injury. Individual player total exposure (exposure to training and match play) up to an injury event or to the end of the season was set as the time variable. Each player season was handled as a separate observation. Covariates were time in professional football (newcomer/established player), age category, and playing position. All covariates were first assessed by simple Cox regression, with results expressed as a hazard ratio (HR) with 95% CI, and thereafter by multiple Cox regression, including all covariates regardless of their significance in the simple analysis. In the multiple regression analyses, club affiliation and match ratio (match exposure/total exposure) were also included as covariates. Club affiliation was included to adjust for variability in injury rates between clubs, and match ratio was included to adjust for potentially uneven distributions of match exposure, since the match injury rate is known to be several times higher than the rate during training (Ekstrand et al., 2011b).

Agreement analysis

In Paper IV, the overall percentage of agreement in injury categorisation was defined as “the number of concordant injury pairs between IBE and TBE audit categorisations/the total number of injury pairs”. Inter-rater agreement was further evaluated using Cohen’s kappa analysis. Kappa values are influenced by the distribution of measured variables (prevalence) and by systematic differences between the data sources (bias) (Byrt at al., 1993). Therefore, Prevalence Adjusted Bias Adjusted Kappa (PABAK) coefficients were calculated, as suggested by Sim and Wright (Sim and Wright, 2005), to assist Kappa interpretations. Since the degree of error is relevant when analysing ordinal data, linear weighted kappa was presented for the variable injury severity. Weighted kappa penalises mismatches with a larger level of error (e.g. minimal vs. severe injury) to a greater extent than mismatches with small level of error (e.g. minimal vs. mild injury).

Kappa and PABAK coefficients are presented with 95% CI. In general, coefficients of 0.81–1.00 are interpreted as almost perfect, 0.61–0.80 as substantial, 0.41–0.60 as moderate, 0.21–0.40 as fair, 0–0.20 as slight and < 0.00 as poor (Landis and Koch, 1977).
ETHICS

The study protocol for *Paper I* was approved by the UEFA Medical Committee and the UEFA Football Development Division. *Paper II* and *Paper III* were approved by the Local Ethics Committees in Linköping, Sweden (Dnr: M240-09), and Region Øst-Norge and the Norwegian Social Science Data, Norway (S-06188). The data collection for *Paper IV* was approved by the UEFA Medical Committee and the UEFA Football Development Division, the Regional Committee for Medical and Research Ethics Region Øst-Norge, and the Norwegian Science Data Services. All papers follow the general ethical guidelines proposed in the Declaration of Helsinki, and written informed consent was obtained from all players.
RESULTS

Paper I

Newcomers compared to established players
Newcomers had a lower mean age compared to established players (18.8 vs. 26.0 years, \( p < 0.001 \)). Newcomers also had lower mean match exposure (22 vs. 41 hours/season, \( p < 0.001 \)) and training exposure (193 vs. 209 hours/season, \( p = 0.03 \)) compared to established players. Newcomers had a significantly lower training injury rate compared to established players (\( \text{RR} 0.76, 95\% \text{ CI} 0.60-0.97 \)), although there was no difference in match injury rate (\( \text{RR} 0.87, 95\% \text{ CI} 0.68-1.13 \)). In contrast, newcomers had a higher injury rate of stress-related bone injuries (\( \text{RR} 2.69, 95\% \text{ CI} 1.08-6.69 \)).

Multivariable risk factor analyses
Simple Cox regression demonstrated that newcomers had a lower injury rate than established players (HR 0.77, 95% CI 0.60-0.96), goalkeepers had a lower injury rate than all outfield playing positions (defenders: HR 1.70, 95% CI 1.47-1.97; midfielder: HR 1.60, 95% CI 1.38-1.85; forwards HR 1.65, 95% CI 1.41-1.93), and the youngest age group (≤ 21 years) had a lower injury rate than all other age groups. The peak injury rate was observed among players aged 29-30 years (HR 1.34, 95% CI 1.16-1.55). The same pattern was repeated in the multiple Cox regression analysis.

Paper II

Injury rates on AT compared to NG
At the individual player level, there were no statistically significant differences in acute match (RR 0.98, 99% CI 0.79-1.22) or training injury rates (RR 1.14, 99% CI 0.86-1.50) when playing on AT compared to NG. When analysing specific injury types, a lower rate of lower leg muscle injuries (\( p = 0.03 \)) during match play was found on AT, and similarly in training, lower rates of lower extremity muscle injuries (\( p = 0.05 \)), in particular, hamstring muscle injuries (\( p = 0.01 \)) were seen on AT, whereas the rate of contusion was higher on AT (\( p < 0.001 \)).

Injury rates for AT clubs compared to NG clubs
AT clubs had a higher acute training injury rate compared to NG clubs (RR 1.31, 99% CI 1.04-1.63), and the same tendency was seen for the match injury rate (RR 1.18, 99% CI 0.98-1.43). When including only the competitive season, this was statistically significant (RR 1.25, 99% CI 1.06-1.48).
The mean seasonal CIR for overuse injury was 40% in AT clubs compared to 32% in NG clubs (RR 1.24, 95% CI 1.08-1.43).

When analysing injury rates according to surface, AT clubs had higher injury rates than NG clubs on both playing surfaces; match play on AT (RR 1.31, 99% CI 0.91-1.91), match play on NG (RR 1.38, 99% CI 1.01-1.89), and training on AT (RR 1.46, 99% CI 0.88-2.41). There was no difference in acute training injury rate on NG between AT clubs and NG clubs (RR 0.95, 99% CI 0.41-2.20). When the two countries were analysed separately, a more prominent difference in acute injury rates between AT clubs and NG clubs was evident for Sweden (match play RR 1.31, 99% CI 0.99-1.72; training RR 1.50, 99% CI 1.10-2.04) compared to Norway (match play RR 1.09, 99% CI 0.83-1.43; training RR 1.19, 99% CI 0.86-1.66).

**Figure 3.** Match and training injury rates over the season, according to the clubs’ home surface. AT, artificial turf; NG, natural grass. Re-printed with permission of the British Journal of Sports Medicine.

**Paper III**

**Surface shifts**

No association was found between the number of surface shifts in the previous match sequence and subsequent overuse injury risk (risk ratio 1.01, 95% CI 0.91-1.12). Similarly, no difference was seen in overuse injury risk after match play on unaccustomed compared to accustomed surface (risk ratio 1.04, 95% CI 0.78-1.38). However, NG clubs had a lower total injury rate when playing away matches on AT compared to away matches on NG (RR 0.66, 95% CI 0.49-0.89).
Climate zones
Analyses based on the whole cohort showed no difference in injury rates between clubs in the two climate zones (total RR 1.01, 95% CI 0.92-1.10). Sub-analyses revealed that NG clubs from snow climate zones had lower training and match injury rates than NG clubs from warm temperate zones (total RR 0.73, 95% CI 0.63-0.84). AT clubs from the snow climate zone had trends towards higher match injury rates compared to AT clubs from the mild temperate climate zone (match RR 1.26, 95% CI 0.99-1.62).

Paper IV

Injury capture rate
Overall, 318 of 323 injuries were registered by the IBE audit (capture rate 98.5%), and 303 of 323 injuries were registered by the TBE audit (93.8%). A larger discrepancy in the capture rate was found for training injuries (IBE audit 185 of 187 injuries, 98.9%; TBE audit 171 of 187 injuries, 91.4%), compared to match injuries (IBE audit 133 of 136 injuries, 97.8%; TBE audit 132 of 136 injuries, 97.1%). We found the same pattern when comparing injury rates based on each audit’s registration of injuries and exposures.

Agreement in injury categorisation
Of the 323 injuries, 298 were registered in both audits and were included in the evaluation of inter-rater agreement for injury variable classification. The overall percentage agreement and Kappa/PABAK coefficients are presented in Table 8.
<table>
<thead>
<tr>
<th>Injury variable</th>
<th>% agreement</th>
<th>( \kappa ) (95% CI)</th>
<th>PABAK (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Injury location</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Injury side</td>
<td>91%</td>
<td>0.85 (0.79-0.90)</td>
<td>0.87 (0.82-0.92)</td>
</tr>
<tr>
<td>Injury location, main</td>
<td>99%</td>
<td>0.94 (0.89-1.00)</td>
<td>0.98 (0.96-1.00)</td>
</tr>
<tr>
<td>Injury location, specific</td>
<td>97%</td>
<td>0.97 (0.95-0.99)</td>
<td>0.97 (0.95-0.99)</td>
</tr>
<tr>
<td><strong>Injury type</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Injury type, main</td>
<td>88%</td>
<td>0.82 (0.76-0.87)</td>
<td>0.86 (0.81-0.90)</td>
</tr>
<tr>
<td>Injury type, specific</td>
<td>88%</td>
<td>0.84 (0.79-0.89)</td>
<td>0.87 (0.84-0.91)</td>
</tr>
<tr>
<td><strong>Injury circumstances</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Injury activity</td>
<td>97%</td>
<td>0.95 (0.91-0.98)</td>
<td>0.95 (0.91-0.98)</td>
</tr>
<tr>
<td>Injury surface(^1)</td>
<td>96%</td>
<td>0.91 (0.86-0.97)</td>
<td>0.95 (0.92-0.98)</td>
</tr>
<tr>
<td>Injury mechanism</td>
<td>91%</td>
<td>0.83 (0.76-0.89)</td>
<td>0.83 (0.76-0.89)</td>
</tr>
<tr>
<td>Injury severity</td>
<td>82%</td>
<td>0.75 (0.68-0.81)</td>
<td>0.76 (0.70-0.82)</td>
</tr>
</tbody>
</table>

CI, confidence interval; \( \kappa \), Kappa coefficient; PABAK, Prevalence Adjusted Bias Adjusted Kappa; \(^1\)Data for surface at injury occurrence was missing for two injuries from the TBE audit. \(^2\)Kappa with linear weighting.
DISCUSSION

Newcomers – young and healthy or more hesitant to seek medical assistance?

Newcomers to professional football had lower injury rates than established players, which was unexpected. It was hypothesised that newcomers would have a higher injury rate due to factors such as a lack of physical adaptation to new training methods. Furthermore, a congested match fixture has previously been shown to increase injury rates in football (Dupont et al., 2010; Bengtsson et al., 2013a). However, during their first season with a professional club, newcomers had a lower mean match exposure compared to established players. Therefore, it is possible that clubs implemented a moderate match load strategy for these newcomers as an injury-prevention strategy.

It could also be speculated that newcomers may be more hesitant to seek medical assistance because of fear of not being selected at matches. Club medical staffs may also pay more attention to the more experienced players with whom they have established relationships, and who have a higher match load. In contrast, newcomers had an increased rate of stress-related bone injuries. A change in total training and match load compared to the academy level could be a contributing factor to this finding. Also, newcomers were significantly younger than their established counterparts, and younger age is an established risk factor for stress fractures in professional football (Ekstrand and Torstveit, 2012).

In contrast to the findings of this thesis, a recent study in Australian Rules football found a significantly increased injury rate among newcomers compared to established players (Fortington et al., 2014). The reason for the discrepancy between codes is unclear, but might be due to differences in the use of player academies, match load on newcomers, or differences in injury definition between the studies (any physical complaint vs. time-loss).

Lower injury rates in the youngest age group

In Paper I, injury rates increased with age, reaching a peak rate among players aged 29-30 years. Previous injury is a well-documented risk factor for re-injury (Hägglund et al., 2006) as well as for new injuries in the same body location (Waldén et al., 2006), and it is reasonable to expect that older players may have suffered more injuries over the course of their career. Having a congested match fixture is associated with higher injury rates in professional football (Dupont et al., 2010; Bengtsson et al., 2013a), and the absence of a continued increase in injury rate for players aged over 30 years may be due to a more moderate match load for the oldest players compared to players in their middle 20s. Also, older players who
are still competing may be less injury-prone than players who retired early from professional football. Thus, selection of less injury-prone players who managed to stay in the open cohort may have contributed to the lack of increase in injury rate also involving the oldest players. In addition, a nonlinear association between age and injury rate was detected in Paper I. Therefore, one plausible reason for the conflicting results in previous studies (Árnason et al., 2004a; Hägglund et al., 2006; Morgan et al., 2001) could be the differences in cut-off values for what is defined as an “old” player.

**Lower injury rates for goalkeepers**

In line with previous studies (Aoki et al., 2012; Árnason et al., 2004b; Ryynänen et al., 2013c), goalkeepers were found to have a lower injury rate than outfield players. No significant differences were found between the outfield players’ injury rates. Importantly, these findings persisted after adjusting for age, time in professional football, and match exposure. Differences in running demands during matches between goalkeepers and outfield players (Di Salvo et al., 2008) may explain the lower injury rate for goalkeepers in general and for muscle injuries in particular. In contrast, goalkeepers had a higher rate of upper extremity and trunk injuries, as well as injuries caused by contact with an object (Paper I). Reaching for the ball may lead to collisions with a goalpost or to unfortunate ball contacts. Also, goalkeepers may be vulnerable to upper extremity and trunk injuries when landing on the ground with their upper extremities away from their body. A large study population is required to study injury patterns among goalkeepers, and the literature regarding injury patterns for professional goalkeepers is mostly limited to case reports. Only one prospective observational study has described injury patterns in goalkeepers compared to outfield players in professional football (Aoki et al., 2012). In that study, goalkeepers were found to have a higher rate of head injuries, a finding not repeated in this thesis. The findings in this thesis suggest that prevention strategies for goalkeepers should have a different focus than strategies for outfield players.

**Acute injury rate on AT compared to NG – where are we now?**

The critical review presented in the background to this thesis, together with the results from Paper II, demonstrate strong evidence suggesting there is no difference in the total injury rate for acute injuries sustained on AT compared to NG. This is supported by the non-significant findings with narrow confidence intervals from various prospective cohort studies, most of them with a robust study methodology and powered to detect clinically relevant differences in total acute injury rates. The studies with highest quality scores have been carried out at the
professional football level (Table 4), and Paper II in this thesis adds a second study reaching moderate level of evidence quality according to GRADE (Grade Working Group, 2004). Only one previous study, in the setting of female amateur football, found a difference in total acute injury rate on the two surfaces (Meyers, 2013). However, the previous study was limited by methodological weaknesses and a clear relationship with the industry producing the product studied.

Aggregated analysis of injury pattern on AT compared to NG

The critical review of the literature presented in the background and the results from Paper II show that all previous published articles are limited by low power for detecting differences in injury pattern between the play on AT compared to NG. Therefore an aggregated-analysis was performed (unpublished results), based on the three prospective cohort studies in men’s professional football analysing acute injury rates on AT and NG (Bjørneboe et al., 2010; Ekstrand et al., 2011a; Paper II). Exposure and acute injury data were aggregated and pooled rate ratios are presented with 95% CIs. This generated a data set of 3302 injuries (1338 training, 1964 match) and 684 563 hours of exposure (576 377 hours from training and 108 186 hours from matches). Analyses were made for specific injury types based on the findings of previous literature: head injury (specific analysis for concussion), muscle injury (specific analyses for quadriceps, hamstring and calf), contusion, and sprain (specific analyses for knee and ankle). These injury types were analysed separately for match injuries and training injuries.

Pooled analyses demonstrated an increased rate for match ankle sprains and for match and training contusions when playing on AT. Pooled data also showed borderline significant result of a decreased injury rate of head/neck injuries and muscle injuries on AT (Table 9, Figure 4).
Table 9. Aggregated analysis of three prospective cohort studies in male professional football studying acute injury rate at artificial turf compared to grass (unpublished data).

<table>
<thead>
<tr>
<th>Match injuries</th>
<th>Acute injuries AT</th>
<th>Acute injuries NG</th>
<th>RR</th>
<th>95% CI</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Injuries (N)</td>
<td>Exposure (h)</td>
<td>IR</td>
<td>Injuries (N)</td>
<td>Exposure (h)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Head injury</td>
<td>47</td>
<td>39395</td>
<td>1.19</td>
<td>113</td>
<td>68791</td>
</tr>
<tr>
<td>Concussion</td>
<td>27</td>
<td>39395</td>
<td>0.69</td>
<td>68</td>
<td>68791</td>
</tr>
<tr>
<td>Muscle injury</td>
<td>204</td>
<td>39395</td>
<td>5.18</td>
<td>412</td>
<td>68791</td>
</tr>
<tr>
<td>Quadriceps</td>
<td>28</td>
<td>39395</td>
<td>0.1</td>
<td>57</td>
<td>68791</td>
</tr>
<tr>
<td>Hamstring</td>
<td>97</td>
<td>39395</td>
<td>2.46</td>
<td>162</td>
<td>68791</td>
</tr>
<tr>
<td>Calf</td>
<td>22</td>
<td>39395</td>
<td>0.56</td>
<td>61</td>
<td>68791</td>
</tr>
<tr>
<td>Contusion</td>
<td>212</td>
<td>39395</td>
<td>5.38</td>
<td>279</td>
<td>68791</td>
</tr>
<tr>
<td>Ligament injury</td>
<td>219</td>
<td>39395</td>
<td>5.56</td>
<td>330</td>
<td>68791</td>
</tr>
<tr>
<td>Knee</td>
<td>48</td>
<td>22096</td>
<td>2.17</td>
<td>118</td>
<td>55212</td>
</tr>
<tr>
<td>Ankle</td>
<td>116</td>
<td>39395</td>
<td>2.94</td>
<td>142</td>
<td>68791</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Training injuries</th>
<th>Acute injuries AT</th>
<th>Acute injuries NG</th>
<th>RR</th>
<th>95% CI</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Injuries (N)</td>
<td>Exposure (h)</td>
<td>IR</td>
<td>Injuries (N)</td>
<td>Exposure (h)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Head injury</td>
<td>28</td>
<td>268066</td>
<td>0.10</td>
<td>30</td>
<td>308311</td>
</tr>
<tr>
<td>Concussion</td>
<td>5</td>
<td>268066</td>
<td>0.02</td>
<td>12</td>
<td>308311</td>
</tr>
<tr>
<td>Muscle injury</td>
<td>237</td>
<td>268066</td>
<td>0.88</td>
<td>248</td>
<td>308311</td>
</tr>
<tr>
<td>Quadriceps</td>
<td>57</td>
<td>268066</td>
<td>0.21</td>
<td>45</td>
<td>308311</td>
</tr>
<tr>
<td>Hamstring</td>
<td>74</td>
<td>268066</td>
<td>0.28</td>
<td>92</td>
<td>308311</td>
</tr>
<tr>
<td>Calf</td>
<td>18</td>
<td>268066</td>
<td>0.07</td>
<td>35</td>
<td>308311</td>
</tr>
<tr>
<td>Contusion</td>
<td>150</td>
<td>268066</td>
<td>0.56</td>
<td>68</td>
<td>308311</td>
</tr>
<tr>
<td>Ligament injury</td>
<td>207</td>
<td>268066</td>
<td>0.77</td>
<td>212</td>
<td>308311</td>
</tr>
<tr>
<td>Knee</td>
<td>40</td>
<td>141794</td>
<td>0.28</td>
<td>70</td>
<td>267390</td>
</tr>
<tr>
<td>Ankle</td>
<td>107</td>
<td>268066</td>
<td>0.40</td>
<td>102</td>
<td>308311</td>
</tr>
</tbody>
</table>

Data included from Bjørneboe et al., 2010; Ekstrand et al., 2011a and Paper II. AT, artificial turf; CI, confidence interval; NG, natural grass; IR, Injury rate expressed as injuries/1000 exposure hours; RR, rate ratio. 1Ekstrand et al., 2011a did not present data for the sub analysis of knee sprain, therefore no data from Ekstrand et al., 2011a is included for this variable.
Figure 4. Aggregated analysis of acute match injury rate on artificial turf (AT) compared to natural grass in men’s professional football (*unpublished data*). Rate ratio >1 = increased injury rate on AT.
Why increased injury rate for AT clubs?

The main finding in Paper II was that, at the individual level, there were no differences in acute injury rates when playing on AT compared to NG. However, at club level, professional football clubs with AT installed at their home venue had a higher acute training injury rate and overuse injury rate compared to clubs with NG at their home venue. Also, the increased injury rate for AT clubs was evident on both playing surfaces, and it is thus unlikely that this can be attributed to high AT exposure per se. It was therefore hypothesised that these findings could conceivably be due to frequent surface shifts or different climates at AT club and NG clubs’ home venues.

Surface shifts

Frequent surface shifts and inadequate adaptation to a new surface has been proposed to be a risk factor for injury, especially overuse injury (Ekstrand and Nigg, 1989; Williams et al., 2011). Since there were fewer AT clubs than NG clubs in the NFIA cohort, players from AT clubs had to alternate between surfaces more often when playing away matches, and this could conceivably contribute to a greater load on musculoskeletal tissues and an increased rate of overuse injuries for AT clubs presented in Paper II. In support of this, in Paper II, the higher match injury rate for AT clubs was only evident during the competitive season when switching between surfaces at away matches occurred frequently, while match injury rates were similar during the pre-season, when most friendly matches were played on AT. The increased injury rates for AT clubs were also most pronounced among the Swedish clubs. This could have been due to the relatively fewer AT clubs in Sweden (4/16 clubs) compared to Norway (7/16), meaning that the Swedish AT club players were required to switch more frequently between surfaces. However in Paper III, this aspect was thoroughly investigated, and the results from this study did not support the hypothesis that match play on unaccustomed surface would be associated with a higher general injury rate. The findings from Paper III suggest the opposite, where NG clubs had a reduced total injury rate when playing away matches on AT compared to away matches on NG. A recent study showed that professional players from clubs with NG installed at their home arena believe that the injury rate is increased when playing on AT, and that some individuals may play with caution on AT due to a fear of sustaining injuries (Poulos et al., 2014). Also, technical analyses have shown a difference in playing style between the two surfaces, where sliding tackles are less common and short passes are more frequently used on AT (Andersson et al., 2007). Perhaps this could lead to a more careful playing style in general when NG clubs play away matches on AT, and
could therefore influence the decreased injury rates observed in this thesis. These differences could also be due to variations in team tactics when playing on an unaccustomed surface.

**Climate**

The role of climate as a potential risk factor for football injury was evaluated in *Paper III*. When including all clubs in the analyses, no difference in injury rate was found between the snow and warm temperate climate zones. However, when analysing AT clubs and NG clubs separately it was found that NG clubs from the snow climate zone had lower injury rates compared to NG clubs from warm temperate climate zones. These results are in accordance with the results from studies of Australian rules football where warmer areas generally had higher injury rates compared to cooler areas (Orchard et al., 2013), but are in contrast with previous studies in European male professional football, where NG clubs from colder areas have been found to have higher injury rates (Waldén et al., 2013). The findings from *Paper III* also showed that AT clubs from the snow climate zone had a trend towards higher match injury rate compared to clubs from the warm temperate zone. Consequently, these results do not support the hypothesis that differences in climate could be the mediating factor of the increased injury rate found among AT clubs in *Paper II*. It is possible that some clubs choose AT turf at their home venue because of the saving in costs. Consequently, differences in club economy could also be a contributing factor to the differences in injury rates observed, and may be appropriate to be addressed in future studies.

**Overuse injuries related to AT**

The analysis performed in *Paper III* showed no association between the number of surface shifts in the preceding five-match sequence and subsequent time-loss overuse injury. Similarly, no difference was found in overuse injury risk after matches played on accustomed compared to unaccustomed surfaces. Previously, biomechanical studies showed no difference in physiological responses after semi-professional matches (Hughes et al., 2012), or football-specific exercises for professional players on AT and NG of high quality (Nédélec et al., 2013). However, 97% of professional players in another setting reported greater muscle and joint soreness after playing on AT (Poulos et al., 2014). Also, previous studies from Swedish male professional football showed that players generally had a negative impression towards AT, including a high rating for physical demands (Andersson et al., 2007). The reason for the obvious discrepancy between players’ perceptions and the scientific literature is unclear. It
may be speculated that football play on AT could still lead to muscle soreness, but in most cases not to the extent that the soreness leads to absence from football activities.

It should be acknowledged that a time-loss definition may substantially underestimate the burden of overuse injuries (Clarsen et al., 2013), and we may thus have been unable to observe a possible association between frequent surface shifts and non-time loss overuse injury risk. Recent studies have recommended that overuse complaints should be monitored on weekly basis and the any physical complaint injury definition should be used (Clarsen et al., 2014). With this approach, it is theoretically possible to objectify the muscle soreness reported from players in previous qualitative studies. However, this approach would increase the data collection burden on the club medical team and might thus be more difficult to carry out than a traditional injury audit. Another possibility for future studies may be to coordinate injury surveillances with journal notes from the club medical team, and in that way using a medical attention definition of injury to capture injury complaints also when players participate fully in team training and match.

Reliability and validity of recordings

Reliability

In the prospective injury registration within this thesis, data collection was based on monthly reports from contact persons in the participating clubs. This evidently creates a risk of discrepancies between different contact persons’ reporting of study data. To establish a reliable registration, a manual was created explaining the definitions used in the study and with examples of how to fill in the forms (Papers I-IV). However, it is still possible that different traditions in assessing diagnosis or injury mechanism might influence the results, for example, if a player with chronic groin pain will be given a general or tissue specific diagnosis or if a hamstring strain is looked upon as an overuse injury or a traumatic injury. Further studies should strive to standardise diagnostic procedures to strengthen the inter-rater reliability in injury surveillance.

Paper IV was the first study to evaluate the level of agreement in injury capture rate and injury categorisation between two research audits studying the same population. The main finding was that high levels of agreement were found in general, which strengthens the study methodology used in this thesis.
Internal validity
The four studies in this thesis rely on the same basic study design, developed in a three-step regime. As a first step in 2000, the UEFA Medical Committee held consensus discussions regarding the study design, methodology and definitions with already existing surveillance system as the basis for discussion. As the second step, the design was implemented in a prospective pilot study in the Swedish and Danish first leagues for one season (2001). Following this, the proposed methodology and definitions, and the experiences from the study group and participating clubs were discussed. After minor revisions the study procedure was approved. This procedure ensured face validity of the study methodology (Hägglund et al., 2005).

Injury and exposure data, sent on a monthly basis from participating clubs, were immediately reviewed by one researcher or a research assistant in the study group. This process provided the opportunity to identify missing data and inaccuracies, and allowed for correction through communication between the study group and club contact persons. Consequently, this procedure strengthened content validity by maximising data completeness and inter-rater reliability. Since this is an observational study, the ecological validity is one of the strengths since teams are observed in their natural environment without any intervention.

External validity
In Paper II and Paper III, 32 of 37 clubs (86%) in Allsvenskan and Tippeligaen agreed to participate (two Swedish clubs and three Norwegian clubs declined participation). This is a high proportion of participation, well in line with previous investigations in professional football (Bjørneboe et al., 2010; Ekstrand et al., 2011a; Hawkins and Fuller 1999; Hägglund et al., 2009a; Waldén et al., 2005). Therefore the results from Paper II and Paper III could probably be generalised to Nordic male professional football in general, but not to other settings such as female players, amateur players or young players.

Strengths and limitations
A prospective design is a key strength of the methodology used in this thesis because it is known to increase the capture rate of injuries compared to retrospective data collection (Junge and Dvorak, 2000). In addition, the registration of individual player exposure allowed for detailed data checking. A general limitation of this thesis was that when analysing injury rate based on what type of surface teams had on their home arena, or which climate zone their
arena was located in, these surface and climate factors could not be randomised. This precluded a randomised controlled trial and introduced a risk of confounding, because potential unknown risk factors could have been unevenly distributed between the groups (GRADE Working Group, 2004). The reporting thresholds for injuries may also vary between different clubs, which is a limitation when comparing injury rates at club level.

**Strengths and limitations in Paper I**

Data for *Paper I* was collected over nine consecutive seasons, among a homogeneous group of male professional football players. A limitation of *Paper I* is that in spite of the large study material, the group of newcomers was relatively small, and this increases the risk of type II errors, especially in the analyses of injury patterns. The group of newcomers also included players who joined a club in the middle of a season. Consequently, these players had only exposure registered from the moment they became a study participant in that season. Therefore, match and training exposure for newcomers might be slightly underestimated in *Paper I*. This was not expected to lead to any meaningful impact on the training/match ratios since these players were few compared to the total sample. No definition of playing positions was given to the included teams and players were categorised into playing positions for the purpose of the study by their clubs before the start of each season. Occasionally players change position during a season and sometimes even during matches, and the categories for playing position used in the present study, and others, may thus be less valid. In addition, the classification does not distinguish if injuries occur in the attacking or defensive zone of the field, nor the actual playing situations that players are exposed to when injured.

**Strengths and limitations in Paper II and Paper III**

A strength of *Paper II* and *Paper III*, is the large homogenous material from two similar professional leagues, over a time-span of two years, in a setting where approximately one-third of the clubs had AT installed at their home venue. This enabled detailed analysis of injury patterns in AT clubs compared to NG clubs. Importantly, the registration of exposure on individual level enabled analysis of surface shifts for individual players, instead of the shift that occurred at the club level. Pre-season training (characterised by a heavy training load) is in Scandinavian football mainly performed on AT. Therefore, an important methodological consideration was to only include data from the competitive season when comparing injury rates on AT with those on NG. Also, the statistical analyses were adjusted for multiple comparisons to decrease the risk for type I errors.
Regarding limitations in Paper II and Paper III, as in previous studies comparing injury rates on AT and NG, distinctions were made between these two general surface types only. All AT surfaces were analysed together, even though various brands from different manufacturers were included. Some artificial turfs include a layer of shock-padding, but the influence on overuse injury rate was not evaluated within this thesis, and has not been evaluated in the previous literature. Similarly, the quality of the NG pitches was not investigated, even though pitch quality is likely to differ between venues due to variations in factors including weather and maintenance. Finally, high frictional forces between the foot and the playing surface is a proposed risk factor for injury, and experimental studies have shown that peak torques vary between different shoe types (Livesay et al., 2006). However, due to the practical problems of registering shoe type, not only at injury but during all activities, the specific influence of shoe type on injury occurrence was not evaluated in these studies.

In Paper II, despite the relatively large study sample, type II errors cannot be ruled out for sub-analyses of specific injury patterns, as shown by the sometimes wide confidence intervals. In Paper III, the cut-off value of a maximum of three days after match for overuse injury risk was chosen arbitrarily. However, the rationale was that (i) training sessions scheduled on the day after a match are usually of low intensity, allowing players with minor overuse complaints to participate, and would thus not be included with a shorter time period than three days, (ii) delayed onset muscle soreness usually peaks after one to two days (Cheung et al., 2003), and (iii) clubs usually play one to two matches per week, allowing the same follow-up period for all injuries. Still, it is unknown if the injury risk would have been affected if another threshold was chosen. Moreover, match result (winning, drawing or losing) is known to affect injury rates in professional football (Bengtsson et al., 2013a) and it is possible that team performance can vary for AT and NG clubs at away matches on unaccustomed surfaces, but this was not evaluated in this thesis. Lastly, data regarding ambient weather conditions at each activity (training and matches), or whether each unique injury was sustained in a warm temperate or snow climate zone were not recorded. Therefore, further research is needed to investigate the influence of weather conditions on injury occurrence.

**Strengths and limitations in Paper IV**

One strength of Paper IV is that since the post-hoc analysis was planned after the prospective data collection was performed, both club physiotherapists and the two research groups were
blinded to the analysis a priori. This means that data were collected as part of the daily routine at each club, and increases the external validity of the results. Also, the fact that data collection took place over two full consecutive football seasons means the effect of potential seasonal variations in injury recordings is reduced. The general similarities found among kappa and PABAK coefficients, suggests that the data were not strongly influenced by bias or prevalence, which by themselves can both increase and decrease the unadjusted kappa value.

In *Paper IV*, both audits simultaneously collected data with support from the same contact person at each club. Both audits may therefore have benefitted from reminders of missing or inaccurate primary data sent by either audit’s controller to the club contact person. Consequently, the independence of the raters (audits) could possibly have been threatened, and the differences in injury capture rates detected in this study are probably at a minimum level. The study design did not allow for evaluation of whether the differences found reflected a discrepancy in information sent from the contact person to each audit or in the data collection process within each audit (including correction of inaccurate data, contact with club contact person regarding missing or uncertain information, and data categorisation). The intention of *Paper IV* was to compare the outcome in general from two different injury audits while studying the same population. A prospective study design is required to identify specific sources of error within the study process. Data in this study is based on injury and exposure data from two clubs. Therefore, the total sample is limited and the results should be verified in future audits of professional football.
CONCLUSIONS

- Newcomers to professional football clubs had a lower training injury rate than established players, but in contrast, a higher rate of stress-related bone injuries.
- The overall injury rate increased with age, a finding that persisted after adjusting for playing position and match exposure.
- Goalkeepers had a lower injury rate in general compared to outfield players, but an increased rate of injuries to the upper extremity and trunk.
- No differences were found between outfield players’ injury rates.
- At the individual level, no differences in acute injury rates were found when playing on artificial turf compared to natural grass.
- At the club level, professional football clubs with artificial turf installed at their home venue had a higher acute training injury rate and overuse injury rate compared to clubs with grass at their home venue.
- The increased injury rate for artificial turf clubs was evident on both playing surfaces, and it is thus unlikely that this can be attributed to high artificial turf exposure per se.
- No influence on overuse injury risk was seen from frequent surface shifts or from playing matches on an unaccustomed surface.
- Clubs normally accustomed to natural grass were found to have a lower injury rate when playing away matches on artificial turf.
- The climate type at Scandinavian clubs’ home venues had minimal influence on injury rates.
- The capture rate for training injuries seems to be slightly higher with individual-based compared to team-based exposure recording.
- Inter-rater agreement in injury categorisation was very high for data registered in two different prospective injury surveillance audits studying the same two Norwegian male professional football clubs.
SUMMARY

This thesis includes four papers based on three different prospective cohort studies on injury characteristics in men’s professional football. The same general methodology was used in all papers. Time-loss injuries and player individual exposure was registered for match and training separately. The general aim was to investigate potential internal and external risk factors for injury, with a focus on age, playing position, time in professional football, playing surface, changes between surfaces and climate; and to evaluate the study methodology.

Paper I was based on data collected between 2001 and 2010 from 26 top professional clubs in Europe; the UCL injury study. In total, 6140 injuries and 797 389 hours of exposure were registered. A decreased general injury rate was observed for newcomers compared to established players (hazard ratio (HR), 0.77; 95% CI 0.61-0.99). Using goalkeepers as a reference, all outfield playing positions had significantly higher age-adjusted injury rates. Using players aged ≤ 21 years as a reference, the overall adjusted injury rate increased with age, with a peak injury rate among players aged 29 to 30 years (HR, 1.44; 95% CI, 1.24-1.68).

Paper II and Paper III are based on data collected during two consecutive seasons, 2010 and 2011, in the Swedish and Norwegian male first leagues. In total, 2186 injuries and 367 490 hours of football exposure were recorded. No statistically significant differences were found in acute injury rates on artificial turf (AT) compared to natural grass (NG) during match play (rate ratio, 0.98, 99% CI 0.79-1.22) or training (rate ratio 1.14, 99% CI 0.86-1.50) when analysing at the individual player level. However, when analysing at the club level, clubs with AT installed at their home arena had a significantly higher acute training injury rate (rate ratio 1.31, 99% CI 1.04-1.63) and overuse injury rate (rate ratio 1.38, 99% CI 1.14-1.65) compared to clubs with NG installed at their home venue. No association was found between frequent surface shifts and subsequent overuse injury risk (risk ratio 1.01, 95% CI 0.91-1.12). Analyses on the total cohort showed no difference in injury rates between clubs in the two climate zones (total rate ratio 1.01, 95% CI 0.92-1.10).

Data included in Paper IV were collected during two consecutive seasons 2008 and 2009. During this period, two Norwegian elite football clubs were concurrently included in two research groups’ surveillance systems. The capture rate for match injuries was similar between the two audits, while the capture rate for training injuries was slightly higher with individual-based exposure recording. The inter-rater agreement in injury variable categorisations was in most aspects very high.
Denna avhandling innehåller fyra olika delarbeten baserade på tre olika prospektiva kohortstudier kring skadekaraktäristik inom professionell herrfotboll. Samma grundläggande metodik användes i alla delarbeten. Frånvaroskador och spelares individuella exponering för fotboll registrerades separat för match och träning. Det generella syftet var att utvärdera potentiella interna och externa riskfaktorer för skada, med fokus på tid inom professionell fotboll, spelarposition, spelarålder, spelunderlag (konstgräs jämfört med gräs), skiften mellan underlag och klimat, samt att utvärdera studiemetodiken.

Delarbete I baseras på data som insamlats 2001 till 2010 från 26 professionella europeiska klubbar som deltagit i UEFA (Europeiska fotbollförbundet) Champions League. Totalt har 6140 skador och 797 389 timmar exponering registrerats. Nykomlingar hade en sänkt generell skaderisk i jämförelse med etablerade spelare (hazard ratio (HR), 0,77; 95% konfidensintervall (KI) 0,61-0,99). Åldersjusterade analyser visade att samtliga utespelare hade en ökad skaderisk jämfört med målvakter. Skaderisken ökade med ålder och de högsta nivåerna sågs bland spelare 29-30 år gamla (HR, 1,44; 95% KI, 1,24-1,68, referens spelare < 21 år).

Delarbete II-III baseras på data som insamlats 2010 och 2011 i svenska och norska högsta ligorna för herrar. Total registrerades 2186 skador och 367 490 timmars exponering. På individnivå fanns ingen skillnad i akut skaderisk mellan spår på konstgräs och gräs, varten i match (rate ratio, 0,98, 99% KI 0,79-1,22), eller träning (rate ratio 1,14, 99% KI 0,86-1,50). Däremot, på klubbnivå hade lag som spelade på konstgräs på sin hemmaarena en ökad skaderisk för akuta träningsskador (rate ratio 1,31, 99% KI 1,04-1,63) samt överbelastningsskador (rate ratio 1,38, 99% KI 1,14-1,65), i jämförelse med gräslag. Ingen association fanns mellan frekventa byten av underlag och efterföljde risk för överbelastningsskada (risk ratio 1,01, 95% CI 0,91-1,12). Analys över totala kohorten visade ingen skillnad i skaderisk mellan lag från olika klimatzoner (total rate ratio 1,01, 95% KI 0,92-1,10).

ACKNOWLEDGEMENTS

Research is team work! I would like to express my sincere gratitude to:

Martin Hägglund, PT, PhD, associate professor at the Department of Medical and Health Sciences, Division of Physiotherapy, Linköping University, Sweden. Main tutor for the second half of my thesis. Also known as Mr Kling. Thank you for your unique ability to have a focus on the small important details as well as the full picture within my project. Your kindness, encouragement and everlasting prompt responses is greatly appreciated. The sharpness in your feedback during tutoring is truly impressive.

Jan Ekstrand, MD, PhD, professor at the Department of Medical and Health Sciences, Division of Community Medicine, Linköping University, Sweden. Main tutor during the first half of my thesis, and assistant tutor during the second half. Thank you for believing in me and introducing me into the world of sports medicine. Your enthusiasm, creativity and knowledge as a researcher is admirable.

Markus Waldén, MD, PhD, senior researcher at Department of Medical and Health Sciences, Division of Community Medicine, Linköping University, Sweden. Also known as Mr Klang (sorry Markus). Thank you for your precise manuscript revisions and your everlasting enthusiasm. Your deep knowledge of sports medicine, as well as stringency and professionalism in research is inspiring.

The participating players and medical contact persons from all participating clubs. It is obvious that this thesis could not be done without you.

Thor Einar Andersen, associate professor, MD, PhD; and John Bjørneboe, MD, PhD both at the Department of Sports Medicine, Oslo Sports Trauma Research Center, Norwegian School of Sport Sciences, Oslo, Norway. Thank you for all the efforts you put into the data collection in the Norwegian part of the cohorts, and for all your valuable input in manuscripts revisions.

Henrik Magnusson, MSc, statistician, Department of Medical and Health Sciences, Division of Physiotherapy, Linköping University, Sweden. Thank you for your meticulous control of my databases – an important factor in the high quality of the data registered during my project. Your unique combination of football and statistical knowledge is invaluable.
Colleagues in the Football Research Group, especially Matilda Lundblad and Håkan Bengtsson. Thank you for your support, friendship and discussions during our scientific meetings and conferences.

Colleagues at the Division of Community Medicine, Linköping University, especially administrator Kajsa Bendtsen, economist Sophie Stoppert Gustafsson, and my roommates Kristin Thomas and Janna Skagerström. Thank you for keeping track on me and for your everyday encouragement.

Colleagues from Region Östergötland, especially Lena Holmertz, Elsa Dahlén, Ann-Charlotte Agnetorn, and Peter Lindstedt, thank you for all your support.

PhD students and senior researchers at the Sports Medicine Seminars at Linköping University, especially Kristofer Hedman, Anne Fältström, professor Joanna Kvist and professor Toomas Timpka. Thank you for your sharp feedback in a friendly atmosphere.

Clare Ardern, PT, PhD, post doc at Department of Medical and Health Sciences, Division of Physiotherapy, Linköping University, Sweden. Thank you for language comments and for interesting discussions during coffee breaks.

Mum and Dad, one research lover and one football lover, a mix of those two and you get me. I have always felt that you are proud of me, whatever I do in life. Both of you symbolise that being compassionate, decent and humble is the way to lead a life. I try to do the same.

My brothers and my sister, thank you for all the debates we have shared around the kitchen table throughout the years. Defending my thesis will be a piece of cake compared to winning a discussion against any one of you. With you in my life I never feel lonely, and I am blessed to be your sister.

Last but not least, Klara. For your love, your constant support, and for making me see what is important in life.

The main financial support for this thesis came from the Swedish National Centre for Research in Sports, Region Östergötland, the Union of European Football Associations, the Swedish Football Association, and Praktikertjänst AB.
REFERENCES


77. Landis JR, Koch GG. The measurement of observer agreement for categorical data. Biometrics. 1977;33:159-74.
93. Orchard J. Research on products such as artificial turf is potentially exposed to the same types of industry bias as research on pharmaceuticals. Br J Sports Med. 2013;47(12):725-726.


## APPENDICES

### Appendix 1. Declaration of consent.

<table>
<thead>
<tr>
<th>Team:</th>
<th>Responsible physician:</th>
<th>Name of player</th>
<th>Date of birth</th>
<th>Height</th>
<th>Weight</th>
<th>Physiotherapy notes</th>
<th>Signature of player</th>
<th>Signature of physician</th>
</tr>
</thead>
</table>

I hereby confirm that I agree to participate in the Nordic Football Injury Audit and that the information provided is for medical and research purposes and will be treated confidentially.

Name of player: ____________________________
Date of birth: ____________________________
Height: _________________________
Weight: _________________________
Physiotherapy notes: _________________________
### Appendix 2a. Training exposure form, excel spread sheet.

<table>
<thead>
<tr>
<th>Club X</th>
<th>Type of training</th>
<th>Type of surface</th>
<th>Player name</th>
<th>Code</th>
<th>Date Exp</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Month X</th>
</tr>
</thead>
</table>

Possible options for type of training:
- F - Football
- O - Other type of training (e.g., strength, endurance, recovery)
- R - Reserve/youth team training
- FO - Football + Other type of training

Possible options for type of surface:
- A - Artificial turf
- G - Grass
- O - Other surface

Possible options for absence:
- AI - Absent from training due to injury
- A - Absent from training due to other reasons
- N - Absent from training due to national team duty

Note: Use the abbreviation FO for a combination of football training and other type of training if this occurs during the same training session (e.g., first 45 min of the training is football training and the last 45 min is strength/endurance training).
### Appendix 2b: Match exposure form, excel spreadsheet

<table>
<thead>
<tr>
<th>Club X</th>
<th>Month X</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of match</td>
<td></td>
</tr>
<tr>
<td>Type of surface</td>
<td></td>
</tr>
<tr>
<td>Player name</td>
<td>Code</td>
</tr>
</tbody>
</table>

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 |

---

**Possible options for absence:**
- **AH** – Absent from match due to injury
- **O** – Absent from match due to other reasons
- **N** – Absent from match due to national team duty

**Possible options for type of match:**
- **F** – Friendly
- **L** – League
- **CL** – Champions League
- **EL** – UEFA Europa League
- **C** – Other cup
- **R** – Reserve/youth team

**Possible options for type of surface:**
- **A** – Artificial turf
- **G** – Grass
- **O** – Other surface
Appendix 2c. National team exposure form, excel spread sheet.
Appendix 3. Injury form.

<table>
<thead>
<tr>
<th>Name:</th>
<th>Code no:</th>
<th>Town:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Date of injury: [ ] Date of return to full participation: [ ]

Injured body part
- [ ] Head/face
- [ ] Neck/shoulder
- [ ] Shoulder/upper arm
- [ ] Upper arm
- [ ] Elbow
- [ ] Wrist
- [ ] Finger/thumb
- [ ] Ankle
- [ ] Foot/ankle

Injury side
- [ ] Right
- [ ] Left
- [ ] Bilateral/cervical

Type of injury
- [ ] Concussion
- [ ] Fracture
- [ ] Other bone injury
- [ ] Ligament/tendon injury
- [ ] Muscle rupture
- [ ] Tendinitis/tenosynovitis
- [ ] Sprain/strain
- [ ] Synovial fluid
- [ ] Nerve injury
- [ ] Overuse symptoms unclassified
- [ ] Dental injury
- [ ] Other (specify)

Diagnosis: [ ]

Was this a re-injury? [ ] Yes (give date of return from previous injury)

Was the injury caused by overuse (gradual onset) or trauma (acute onset)?
- [ ] Overuse
- [ ] Trauma/acute
- [ ] Not applicable

When did the injury occur?
- [ ] Training
- [ ] Race
- [ ] Other
- [ ] Match (min. of injury)
- [ ] Not applicable

Indicate type of training or match where injury occurred
- [ ] Football training (F)
- [ ] Friendly match (F)
- [ ] League match (L)
- [ ] UEFA Champions League match (CL)
- [ ] UEFA Europa League match (EL)
- [ ] National team training (N)
- [ ] National team match (NM)
- [ ] Other (specify)

Indicate playing position at time of injury
- [ ] Goalkeeper
- [ ] Defender
- [ ] Midfielder
- [ ] Forward
- [ ] Other (specify)

Indicate surface where injury occurred
- [ ] Grass (G)
- [ ] Artificial turf (A)
- [ ] Other surface (O)
- [ ] Not applicable

Was the injury caused by contact or collision?
- [ ] No
- [ ] Yes, with other player
- [ ] Yes, with object (specify)

Injury mechanism
- [ ] Running
- [ ] Twisting/turning
- [ ] Falling/diving
- [ ] Slaming
- [ ] Sliding
- [ ] Diving
- [ ] Other (specify)
- [ ] Hit by ball
- [ ] Kicked by other player
- [ ] Bowled
- [ ] Other (specify)

Injury mechanism (describe in own words)

Referee's sanction
- [ ] No foul
- [ ] Opponent foul
- [ ] Out of fouling
- [ ] Yellow card
- [ ] Red card

Other comments: [ ]
Papers

The articles associated with this thesis have been removed for copyright reasons. For more details about these see:
http://urn.kb.se/resolve?urn=urn:nbn:se:liu:diva-117170