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Epidemiology of injuries in elite football

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“Some people believe football is a matter of life and death. I am very disappointed with that attitude. I can assure you it is much, much more important than that.”

Bill Shankly (1913-1981), legendary manager of Liverpool FC

PREFACE

Football has been an essential part of my life since early childhood and my first organised steps on the pitch occurred in 1981. Unfortunately, I sustained a rupture of the anterior cruciate ligament in my right knee during the second match of the competitive season in 1994. After reconstructive surgery and rehabilitation during 1995, I continued to play some inter-company football between examinations at medical school. However, my football career was finally ended when I suffered a re-rupture in 1997. In addition to the torn cruciate, I have also during my short career in senior football suffered from a pelvic avulsion fracture, a severe sprain to my left ankle and a scalp wound requiring five stitches after a clash of heads.

Quite logically, my interest in sports medicine grew and I began to wonder why some athletes are more injury-prone than others and what risk factors are involved. After I graduated from medical school in Lund 2001, Professor Jan Ekstrand presented this project to me and invited me to become his PhD student. The meaning of the expression “an offer one cannot refuse” was suddenly completely obvious to me. Through this six-year PhD project, I have been able to keep close contact with the sport, and watching matches live or on television has been equivalent to work. This thesis, however, is not the work of a single man as everyone understands. As a former football player, it has therefore been a pleasure to work in a team with so many talented team mates. I also have the great opportunity to implement knowledge from my research in real life, since I am the team physician for a women’s sub-elite team and the Swedish men’s U-16 national team.

Football is the most popular sport worldwide, also known as soccer in North America, but the term football is consistently used in this thesis. I would also like to point out that it is beyond the scope to completely review the current literature, since the number of published studies on football injuries has increased dramatically over the last decade. The results presented in this thesis are therefore basically compared with studies conducted on senior elite football played outdoors. The elite level is usually defined as international football as well as the two highest national leagues for men and the highest national league for women. The studies cited should in general have included players from more than one team or club, and results from amateur or youth football are not included unless the findings are specifically relevant. Finally, although most interesting, I have no intention of comparing the findings in this thesis with those from other sports.

Linköping 2007/05/04

Markus Waldén

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INTRODUCTION

History of football

Football is the most popular sport worldwide. The earliest described form of the game comes from a military manual during the Han Dynasty in China dating to the second or third century BC (www.fifa.com). In this game, a leather ball filled with feathers and hair was kicked through a small opening into a net attached to bamboo canes. During subsequent decades, many different forms of the game were developed all over the world. The milestone of the modern sport was when association football and rugby football branched off in their different courses and the first football association was founded in 1863 in England. The spread of football outside Great Britain, however, was initially quite slow and the Federation of International Football Associations (FIFA) was not founded until 1904. The Swedish Football Association was founded the same year while the Union of European Football Associations (UEFA) was founded as late as 1954.

In the beginning of the 20th century, football was a sport played exclusively by men. However, women's football is growing fast and it is now played in around half of the 207 member federations of FIFA (www.fifa.com). At the moment, there are approximately 250 million licensed players of both sexes worldwide (www.fifa.com). Around one-tenth of these players belong to the 53 member federations of UEFA (www.uefa.com). The first men's World Cup was arranged in 1930, but the first women's World Cup did not take place until 1991. Similarly, the European Championship for men was played for the first time in 1960 and for women in 1984. These tournaments are now both played every fourth year meaning that a major international championship follows immediately after the league season every second year.

Even if Sweden was one of the pioneer countries regarding women's football (the elite league played for the first time in 1973), the inaugural men's elite league had already been played in 1924. During 2005, there were around 250000 licensed football players in Sweden and almost one-quarter were females (www.svenskfotboll.com). The players in the men's elite league are nowadays full-time professionals with few exceptions,^{67,72} but women's elite football still has the status of an amateur or semi-professional game with only a few full-time professionals.^{72,79}

Game of football

The profile of the sport has not been substantially changed over the past century and is thoroughly regulated in the "Laws of the Game".⁴⁴ The playing field has a maximum length of 105 m and width 68 m, with natural grass, artificial turf and gravel as the most common surfaces. An official match in senior and higher-age youth football consists of two 45-minute halves with a half-time break of 15 minutes.

Today's outdoor football involves two teams of eleven players each, including the goalkeeper. The standard distribution of player positions (goalkeeper, defenders, midfielders and strikers) has changed with time. Common starting line-ups nowadays include 1-4-4-2, 1-4-3-3 or 1-4-5-1. In modern "total" football, however, all players participate in offensive actions when their own team is controlling the ball and conversely all players participate in defensive play when the opponent team possesses the ball.

Although it has been stated that the sport has become faster and is played at a higher intensity in recent decades,¹³⁷ the distance covered during a top level football match has been fairly constant at 10-12 km for outfield players.^{130,137} Midfielders cover the longest distance of all players and professionals cover a longer distance than amateur players. The average work intensity during a match is between 80-90% of the maximum heart rate and is thus very close to the anaerobic threshold.

Football calendar

The league calendar of most European federations typically consists of a pre-season preparation period followed by a subsequent double round-robin competitive season. Due to the arctic climate, the season is different in the four most northern Nordic countries compared to the rest of Western Europe.⁶⁸ In Sweden, pre-season preparation starts already in December or January after an off-season period of 4-6 weeks. Football training outdoors on natural grass is not possible until the second half of March in southern Sweden and even later in the northern parts. The competitive season starts in early April and normally ends in late October. In most other European countries, however, the pre-season preparation period lasts from the beginning of July to the middle or the end of August.¹⁴⁵ The following competitive season ends in May or sometimes in the beginning of June. Most countries have a varying winter break, but England, for instance, has no break at all during the season and this has recently been a matter of debate.³⁸

The number of clubs in the highest men's leagues in Europe varies slightly, but as a rule the number of teams and thereby also the number of matches are higher than in Sweden. In addition to league matches, clubs also participate in friendly matches during the pre-season and national cup matches during the competitive season. Successful clubs participate also in the Champions League or UEFA Cup and they can therefore play as many as 60-70 matches per year.³⁷ A significant proportion of the top-class players are also exposed to international duties which further increases the number of matches for the individual player. It should, however, be noted that female elite players in general are exposed to fewer matches than their male counterparts.⁷² The women's elite leagues in Europe have fewer teams compared to men's elite leagues. In addition, there is only one international Cup, the Women's Cup, in which all league winners compete. The format of this cup is also smaller than both the men's Champions League and UEFA Cup.

LIST OF PAPERS

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

Paper I

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

Paper II

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

Paper III

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

Paper IV

Waldén M, Häggglund M, Ekstrand J. Football injuries during European Championships 2004-2005. *Knee Surg Sports Traumatol Arthrosc* 2007;in press.

Paper V

Waldén M, Häggglund M, Ekstrand J. Anterior cruciate ligament injuries in elite football: the influence of gender and age. In manuscript.

In addition to *Papers I-V*, some hitherto unpublished observations will be presented in this thesis and are referred to as (*unpublished results*). All reprints (*Papers I-IV*) were produced with the permission of the publishers.

DESCRIPTION OF CONTRIBUTION

Paper I

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

Paper II

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

Paper III

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

Paper IV

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

Paper V

Study design	Markus Waldén
Data collection	Markus Waldén, Martin Hägglund
Data analysis	Markus Waldén, Martin Hägglund
Manuscript writing	Markus Waldén
Manuscript revision	Martin Hägglund, Jan Ekstrand

REVIEW OF PAPERS

Paper I

Injuries in Swedish elite football - a prospective study on injury definitions, risk for injury and injury pattern during 2001

Introduction: Although there are many studies investigating the injury characteristics of men's football, no study has prospectively compared different injury definitions.

Objective: To study the risk of injury and injury pattern in the Swedish men's elite league and to compare the time loss and tissue injury definitions.

Subjects & methods: All 14 teams (310 players) were studied during the full 2001 season. Time loss injuries and tissue injuries were recorded prospectively as well as the individual training and match exposure.

Results: In total, 240 players incurred 765 tissue injuries and 238 players incurred 715 time loss injuries. There were no differences in injury incidence between the definitions during match play (27.2 ± 17.0 vs. 25.9 ± 16.0 injuries per 1000 hours, $p=0.66$) or training (5.7 ± 3.7 vs. 5.2 ± 3.2 injuries per 1000 hours, $p=0.65$). Significantly higher time loss injury incidences were found during the pre-season compared to the competitive season for training injury (8.0 ± 4.9 vs. 3.7 ± 2.3 injuries per 1000 hours, $p=0.001$), overuse injury (4.2 ± 2.9 vs. 2.1 ± 2.2 injuries per 1000 hours, $p<0.01$) and re-injury (2.7 ± 3.0 vs. 1.3 ± 1.2 injuries per 1000 hours, $p=0.02$). Thigh strain was the single most common injury (14%).

Conclusions: No difference in injury incidence was seen between the two injury definitions. Pre-season was associated with higher rates of training injury, overuse injury and recurrent injury. Thigh strain was the most frequent injury.

Paper II

High risk of new knee injury in elite footballers with previous anterior cruciate ligament injury

Introduction: Anterior cruciate ligament (ACL) injury is a severe event for a footballer, but it is unclear if the knee injury rate is higher after returning to football following ACL injury.

Objective: To study the risk of new knee injury in male elite footballers with a history of ACL injury compared to players without.

Subjects & methods: Players with a history of previous ACL injury were identified at the start of the study on the Swedish men's elite league 2001. Individual exposure to football and time loss injuries were recorded prospectively during the season. Analyses were performed using both the player and the knee as the unit of analysis.

Results: In total, 24 players had a history of 28 ACL injuries in 27 knees (one re-rupture). The proportion of players with a history of previous ACL injury who suffered at least one new knee injury during the season was significantly higher than in players without (50% vs. 21%,

$p=0.004$). Players with a history of previous ACL injury had also a higher incidence of new knee injury than the rest of the players (4.2 ± 3.7 vs. 1.0 ± 0.7 injuries per 1000 hours, $p=0.02$). The incidence of new knee injury was significantly higher both when using the player (relative risk 3.4, 95% CI 1.8-6.3) and the knee (relative risk 4.5, 95% CI 2.3-8.8) as the unit of analysis.

Conclusions: The incidence of new knee injury was significantly increased after return to elite football following ACL injury. The increased risk was seen both when using the player and the knee as the unit of analysis.

Paper III

UEFA Champions League study: a prospective study of injuries in professional football during the 2001-2002 season

Introduction: No study has investigated the incidence and pattern of injuries in football at the highest club competition level involving different countries.

Objective: To study the injury characteristics among professional football clubs from several European countries.

Subjects & methods: Eleven clubs (266 players) in the men's elite leagues of five European countries were studied during the 2001-2002 season. All time loss injuries were recorded prospectively as well as the individual training and match exposure.

Results: In total, 658 injuries were recorded among 225 players. The match injury incidence was 30.5 ± 11.0 injuries per 1000 hours and the training injury incidence was 5.8 ± 2.1 injuries per 1000 hours. The incidence of match injury was higher for the English and Dutch teams compared to the Mediterranean teams (41.8 ± 3.3 vs. 24.0 ± 7.9 injuries per 1000 hours, $p=0.008$) as well as the incidence of severe injury with absence more than four weeks (2.0 ± 0.5 vs. 1.1 ± 0.6 injuries per 1000 exposure hours, $p=0.04$). Players with international duty had a higher match exposure (42 ± 15 vs. 28 ± 15 , $p<0.001$), but a tendency towards a lower training injury incidence (4.1 ± 2.4 vs. 6.2 ± 2.7 injuries per 1000 hours, $p=0.051$). Thigh strain was the most common injury (16%) with posterior strains being more frequent than anterior ones (67 vs. 36, $p<0.0001$).

Conclusions: Regional differences had an influence on injury epidemiology. National team players had a higher match exposure, but no higher risk of injury than other professional players. The most common injury was hamstring strain.

Paper IV

Football injuries during European Championships 2004-2005

Introduction: Few studies have compared the injury characteristics of men's and women's football and the risk of training injury during international championships is not known.

Objective: To study the injury characteristics of three European Championships and to compare data for men, women and male youth players.

Subjects & methods: The national teams of all 32 countries (672 players) that qualified to the men's European Championship 2004, the women's European Championship 2005 and the men's Under-19 (U-19) European Championship 2005 were studied during the tournaments. Individual training and match exposure were documented prospectively as well as all time loss injuries.

Results: In total, 80 injuries were recorded among 73 players. The overall injury incidence was fourteen times higher during match play than during training (34.6 ± 32.8 vs. 2.4 ± 4.7 injuries per 1000 hours, $p < 0.0001$). There were no differences in the match and training injury incidences between the championships. Teams eliminated after the group stage in the women's championship had a significantly higher match injury incidence compared to teams going to the semi-finals (65.4 ± 34.3 vs. 5.0 ± 10.1 injuries per 1000 hours, $p = 0.02$). Non-contact mechanisms were ascribed to 41% of the match injuries. A significantly higher frequency of non-contact injury was seen in the second compared to the first half of matches (71% vs. 41%, $p = 0.049$).

Conclusions: The risk of injury in men's and women's international football was similar, but the teams eliminated in the women's championship had a higher match injury incidence than the teams that were going to the final stage. The frequency of non-contact injury was high, especially in the second half of matches.

Paper V

Anterior cruciate ligament injuries in elite football: the influence of gender and age

Introduction: Some studies have found a higher risk of ACL injury and a lower age at injury among female football players.

Objective: To identify players with a history of previous ACL injury in the Swedish elite leagues and to study and the incidence of ACL injury taking gender and age into account.

Subjects & methods: All 12 clubs in the women's elite league (228 players) and 11 of 14 clubs in the men's elite league (239 players) were studied during 2005. Player age and the history of previous ACL injury in the player's career were recorded at the start of the study. Individual exposure to football and the occurrence of ACL injury were recorded prospectively during the season.

Results: The prevalence of a history of previous ACL injury at baseline was higher among the female players (15% vs. 5%, $p = 0.0002$). During the season, 16 ACL injuries were recorded and there was a tendency of a lower mean age at injury among the females (20 ± 2 vs. 24 ± 5 years, $p = 0.069$). Adjusted for age, no gender-related difference in the risk of ACL injury was seen (relative risk 0.99, 95% CI 0.37-2.6). Age was associated with ACL injury incidence in women where the risk decreased by 24% for each year increase in age (relative risk 0.76, 95% CI 0.59-0.96).

Conclusions: The prevalence of previous ACL injury was significantly higher in the female elite players, but there was no gender-related difference in the incidence of ACL injury. Increasing age was associated with a decreasing risk of ACL injury in women.

ABBREVIATIONS

The following abbreviations, listed in alphabetical order, are used in this thesis:

ACL	Anterior cruciate ligament
ANOVA	Analysis of variance
CI	Confidence interval
DOMS	Delayed onset muscle soreness
DRG	Diagnosis-related group
FA	Football Association
FIFA	Federation of International Football Associations
F-MARC	FIFA medical assessment and research centre
HR	Hazard ratio
ICD	International classification of diseases
KOOS	Knee injury and osteoarthritis outcome score
MCL	Medial collateral ligament
MRI	Magnetic resonance imaging
OSICS	Orchard sports injury classification system
ROM	Range of motion
RR	Rate ratio
SD	Standard deviation
UEFA	Union of European Football Associations
U-19	Under-19
U-21	Under-21

BACKGROUND

Sports injury surveillance

It has been suggested that epidemiological sports injury research should ideally follow a four-step sequence of prevention as seen in Figure 1.¹³⁹ First, the problem needs to be identified and described in terms of incidence and severity. In the second step, the factors and mechanisms which play a part in the occurrence of injuries should be identified. The third step is to introduce preventive measures based on the aetiological factors and mechanisms identified in the second step. Finally, the effect of these measures is evaluated by simply repeating the first step. Alternatively, the effectiveness of the measures can also be assessed in a randomised controlled trial.¹⁴⁰

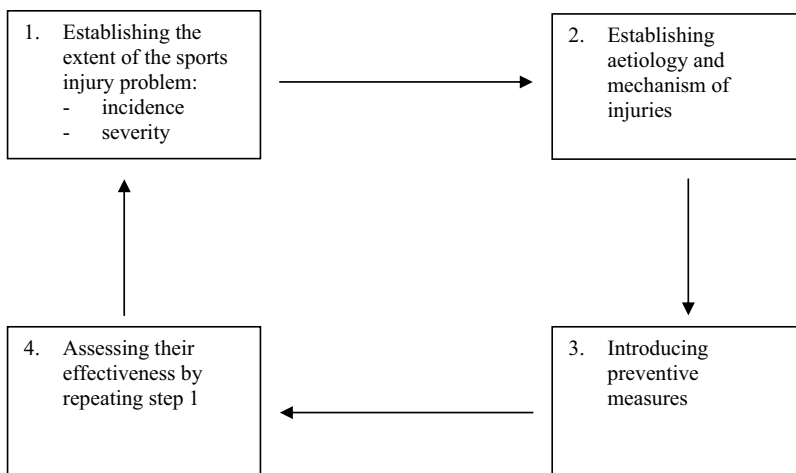


Figure 1. The sequence of prevention developed by van Mechelen et al.¹³⁹ Reprinted with the permission of Sports Medicine, Adis International, Wolters Kluwer Health.

The principle of the sequence of prevention cannot be applied without proper sports injury surveillance research in the first step. Many authors have, however, repeatedly pointed out the dilemma that there has been no consensus in study design, data collection procedure and injury definitions.^{21,26,29,35,65,69,74,81,89,111,139} With respect to football, a methodological consensus was therefore recently created by representatives from the major football research groups in the world.⁵³

Injury definition

There are several definitions of what constitutes a sports injury in the literature.^{29,74,81,111,144} Injury can principally be defined as incident resulting in time loss from participation, physical damage, medical attention, hospital treatment, or insurance claim. Obviously, there is no ideal definition of sports injury and there are advantages as well as limitations for each definition.³⁵ The football consensus group recently recommended that a football injury should be defined as “any physical complaint sustained by a player that results from a football match or football

training, irrespective of the need for medical attention or time loss from football activities".⁵³ This definition closely resembles the anatomical tissue injury definition used in a few recent studies on players of different ages and variable levels of skill.^{81,85,116} Historically, however, defining injury according to time loss has been most widely used when studying the injury characteristics of elite football. It requires the player to have missed at least one training session or match,^{9-11,40,41,72,78,80,110,143,151} the next training session or match,^{12,14,33,36,37,67,68,70,117} the next day,^{3,4,6,13,28,42,43,62} or the next two days.^{63,95,145-147} Defining injury according to medical attention was introduced more recently and denotes any physical complaint receiving medical attention from the team physician or other medical practitioner.^{49,55,84,88,106} Although not used in elite football exclusively, some studies have reported the amount of football-related injuries among patients attending hospital casualty departments^{73,90,98,149} or other health care clinics.²⁵ Finally, other studies have taken their data from insurance files.^{18,39,46,119,127}

Exposure and injury incidence

Regardless of the injury definition used, injury incidence should be calculated as a ratio between adequate numerator data and denominator data.⁹⁶ Common numerator data in the literature are the number of injured players or the number of sustained injuries during a particular period. Similarly, common denominator data are the number of athletes at risk, the number of athlete-exposures, or the time of participation in the sport. The importance of collecting exposure data has been emphasised in several studies.^{21,26,96,111}

Injury incidence should preferably be expressed as the number of injuries per 1000 hours of participation.¹³⁹ However, reporting the number of injuries per 1000 athlete-exposures has been common, for instance, in studies on American college football.^{2,7,8,94,104} Since the duration of each exposure varies, the injury incidence will be different if using player-exposure instead of player-hour,²¹ and this is therefore no longer recommended.⁵³

Data collection

Historically, there have also been great discrepancies between studies regarding their procedures of data collection. Usually one of the coaches is responsible for completing the exposure form, at least during training.^{9-11,13,33,40-43,67,78,99,110,143,151} In some studies, the official match records have been obtained to adequately cover individual match exposure.^{10,11,13,143} In other studies, exposure details were filled in by the team physician^{36,99} or a coach, the team physical therapist or the team physician as preferred by each club.^{68,70,72} From the recent work of the consensus group, it is recommended that the exposure report form should preferably be filled in by a coach after each training session and match.⁵³

The injury form should optimally be completed by a medical professional as soon as possible after the event.⁵³ The team physician or the team physical therapist has been responsible for diagnosing the injuries in most studies.^{3,4,6,9-13,28,33,36,40,42,49,62,84,85,88,99,143,145-148,151} However, the optimal frequency of reporting data to the register has not been studied or discussed in the literature. Studies on tournaments have typically collected the forms after each match.^{84,85,88} On the other hand, studies investigating day-to-day elite football over a full season or part of it have typically collected data on a monthly basis^{4,6,10-13,33,37,68,70,72,80,99,110} or sometimes weekly.^{42,63,78,145-147}

Risk of football injury

As a contact sport, football is associated with an inbuilt risk of injury. In fact, the risk of injury has been shown to be approximately 1000 times higher in professional footballers compared to common industrial occupations generally regarded as high risk.²⁸ The incidence of football injury has been reviewed several times during the past 10-15 years.^{29,56,74,87,144} Most studies included in these reviews have been conducted on men's senior or youth football, but the literature on injuries in women's senior football is quite scarce. It is furthermore difficult to compare older-age adolescent football with senior football, since the player ages in the studies often overlap.⁸¹ The upper age range in many studies on youth football is 18 or 19 years,^{76,83,86,133} and conversely the lower age range in senior football studies is often 16 or 17 years.^{9,10,33,41,99,106}

Table 1. Studies reporting time loss injury incidence (number of injuries per 1000 hours) in men's senior elite or professional football.

Study	Country	Study period	Population	Match	Training
Andersen et al. ⁶	Norway	1 competitive season 2000 (April-October)	14/14 division I teams, around 330 players	21.5*	--
Árnason et al. ⁹	Iceland	1 competitive season 1991 (May-September)	5/10 division I teams, 84 players	34.8	5.9
Árnason et al. ¹⁰	Iceland	1 competitive season 1999 (May-September)	17/20 division I-II teams, 306 players	24.6*	2.1*
Ekstrand & Tjøpp ³³	Sweden	1 full season 1980 (January-December)	9/12 division I teams, 135 players	21.8	4.6
			12/12 division II teams, 180 players	18.7	5.1
Engström et al. ⁴⁰	Sweden	1 full season 1987 (January-December)	3 division I-II teams, 64 players	13	3
Hawkins & Fuller ⁶²	England	3 seasons 1994-1997 (November-May)	4 division I-III teams, 108 players	25.9	3.4
Häggglund et al. ⁶⁷	Sweden	1 full season 1982 (January-October)	8/12 division I teams, 118 players	20.6	4.6
Häggglund et al. ⁶⁸	Denmark	1 spring season 2001 (January-June)	8/12 division I teams, 188 players	28.2	11.8
Häggglund et al. ⁷⁰	Sweden	1 full season 2002 (January-November)	12/14 division I teams, 262 players	22.7	5.3
Häggglund ⁷²	Sweden	1 full season 2005 (January-October)	11/14 division I teams, 239 players	28.1	4.7
Nielsen & Yde ¹¹⁰	Denmark	1 full season 1986 (January-November)	2 division II teams, 34 players	18.5	2.3

* Only traumatic injuries

Men's senior football

Except for one study,⁶⁸ the risk of time loss injury during training is fairly constant between 2.1 and 7.6 injuries per 1000 training hours regardless of playing level.^{9,31,33,36,40,62,67,70-72,110,117} On the other hand, the risk of match injury seems to increase with level of play reaching a plateau at the highest club competitive or international level. The match injury incidence in amateur football has been reported to be 11.9-20.7 injuries per 1000 match hours,^{31,33,72,110,117} but up to 34.8 injuries per 1000 match hours in elite football.^{6,9,10,13,33,40,62,67,68,70,72,110,117} All prospective studies reporting time loss injury incidences for more than one senior men's elite or professional football team during at least one competitive season without any interventions are summarised in Table 1. In addition, studies on international duty have found 29 traumatic match injuries per 1000 hours for the Norwegian Under-21 (U-21) team during 1994-1998 and 30.3 match injuries per 1000 hours for the Swedish senior team during 1991-1997.^{3,36}

Two studies using a medical attention injury definition have also investigated the risk of injury in men's elite football.^{99,106} The first survey defined injury according to a combination of time loss and medical attention as an incident occurring in scheduled matches or training sessions causing the player to interrupt the match or training and to contact the physician.⁹⁹ In that study, 263 players of all 12 clubs in the elite league in Finland were studied during the 1993 competitive season (April-October). They found injury incidences of 16.6 injuries per 1000 match hours and 1.5 injuries per 1000 training hours, respectively. The second study was conducted on the inaugural season (March-December) of the American professional league during 1996.¹⁰⁶ Injury was defined as an incident reported to and evaluated by the team athletic trainer or team physician. The injury incidence for 237 players in 10 clubs was 35.3 injuries per 1000 match hours and 2.9 injuries per 1000 training hours. In addition, 21 players competing in the two highest leagues of the Czech Republic were studied during the full 1997-1998 season (May-May) as part of a larger cohort.¹¹⁶ Injury was defined as any tissue damage caused by football regardless of the consequences with respect to absence from training or match and the match injury incidence was found to be 18.6 injuries per 1000 hours.

Women's senior football

All eight prospective studies reporting on the injury incidence for more than one senior woman's team, regardless of the level of play, are shown in Table 2. With the exception of the study on American professional football,⁵⁵ all studies use a time loss injury definition and actually six of them are Swedish.^{41,42,72,77,78,134,151} The most recent study is the only one which has included both men and women.⁷² In that study, the injury incidence was significantly lower, especially during match play, in women's compared to men's elite football. In spite of fewer studies conducted in the field, the overall risk of injury in women's football seems to be more similar to that reported for men's amateur football. Whatever, the risk of injury does not seem to be higher in women's compared to men's elite football.

International championships

Several studies on senior international championships from the FIFA Medical Assessment and Research Centre (F-MARC) further support the impression that women's football is associated with a lower risk of injury.^{84,85,88} The reported match injury incidences using either a tissue injury or medical attention injury definition are shown in Table 3.

Table 2. Studies reporting time loss or medical attention injury incidence (number of injuries per 1000 hours) in women's senior football.

Study	Country	Study period	Population	Match	Training
Engström et al. ⁴¹	Sweden	1 full season 1988 (January-December)	2 division I-II teams, 41 players	24	7
Faude et al. ⁴²	Germany	1 full season 2003-2004 (August-June)	9/12 division I teams, 165 players	23.3	2.8
Giza et al. ⁵⁵	USA	2 full seasons 2001-2002 (February-August)	8/8 division I teams, 202 players	12.6	1.2
Häggglund ⁷²	Sweden	1 full season 2005 (January-October)	12/12 division I teams, 228 players	16.1	3.8
Jacobson & Tegner ⁷⁷	Sweden	1 full season 1998 (January-October)	18/20 division III teams, 253 players	13.3	8.4
Jacobson & Tegner ⁷⁸	Sweden	1 full season 2000 (January-October)	12/12 division I teams, 269 players	13.9	2.7
Söderman et al. ¹³⁴	Sweden	1 competitive season 1998 (April-October)	13 division II-III teams, 146 players	10.0*	1.3*
Östenberg & Roos ¹⁵¹	Sweden	1 competitive season 1996 (April-October)	8 division I-V teams, 123 players	14.3	3.7

* Only traumatic injuries to the lower limbs

The incidences were consistently lower among women (39-70 injuries per 1000 hours) compared to their male counterparts (73-113 injuries per 1000 hours). These incidences are considerably higher than those listed in Table 1 in studies using a time loss injury definition. For some of the FIFA championships, however, the expected time loss injury rates were also calculated. These figures were more similar to those found in Table 1, but the injury rate was still lower among women (24-30 injuries per 1000 match hours) than among men (29-51 injuries per 1000 match hours).

Table 3. Studies reporting tissue injury or medical attention injury incidence (number of injuries per 1000 match hours) during senior FIFA international championships.

Study	Championship	Population	Gender	Incidence
Junge et al. ⁸⁴	World Cup 2002	32 national teams, 704 players	Men	81.0
Junge et al. ⁸⁵	World Cup 1998	32 national teams, 704 players	Men	72.8
	World Cup 1999	16 national teams, 320 players	Women	38.7
	Olympic Games 2000	16 national teams, 288 players	Men	113.4
	Olympic Games 2000	8 national teams, 144 players	Women	64.6
Junge et al. ⁸⁸	Olympic Games 2004	16 national teams, 288 players	Men	73
	Olympic Games 2004	10 national teams, 180 players	Women	70

Nature of football injury

Time loss

The majority of all time loss injuries in men's and women's elite football affect the lower extremities (77-93%).^{9,10,40-42,62,63,68,70,72,78,106} The ankle and knee joints are the most frequent injury locations in women's elite football.^{41,42,78} These locations also used to be most frequent in men's elite football,^{40,106,110,117} but in several recent studies thigh injuries have been most common.^{10,62,63,68,70,72,84,88,145} The three most common traumatic injury types in the literature are sprains, strains and contusions.^{9,10,40-42,62,63,68,70,72,78,106} However, the relative frequencies differ between studies. Sprains constitute 17-34% of all time loss injuries and usually affect the ankle or knee joints. Strains constitute 10-42% of the injuries and are located primarily to the thigh followed by the groin and lower leg. Contusions are slightly less frequent than both sprains and strains (8-21%), but can in contrast affect almost each location. Fortunately, fractures are quite uncommon (1-5%).

Apart from the findings of one small study conducted two decades ago (8%),⁴⁰ thigh injuries have recently constituted between 21-24% in men's and 15-23% of all injuries in women's elite football, respectively.^{10,41,42,62,63,68,72,78} In the most current study, comparing the Swedish men's and women's elite leagues 2005, thigh injuries were found to be equally divided between the sexes.⁷² The majority of all thigh injuries are strains and they constitute in turn 10-22% and 10-19% of injuries in men's and women's elite football.^{9,10,42,63,68,72,106} Anterior strains typically involve the rectus femoris muscle and is associated with kicking,⁹³ while posterior strains most often affects the biceps femoris muscle and occur during sprinting activities.^{93,147} From studies on men, it is known that the posterior thigh is involved more often than the anterior thigh and typically between 67-88% of the thigh strains have involved the hamstrings.^{9,10,63,106}

Knee injuries constitute between 15-21% and 19-25% of all injuries in men's and women's elite football, respectively.^{10,41,42,62,63,68,70,72,78,106} Most knee injuries are sprains and injury to the medial collateral ligament (MCL) is the single most common knee injury, representing around three-quarters of all knee sprains.^{62,63,145} ACL tear is, however, the injury that has interested most researchers, although it represents less than 5% of all injuries in elite football.^{9,10,40-42,55,99} Several frequently cited studies have found a higher rate of ACL injury among female football players compared to their male counterparts.^{2,7,8,19,104,125,129} None of these studies, however, was conducted on the field in an elite environment. In studies on elite football, no obvious gender-related difference in the proportions of knee sprain (6-10% in women and 6-9% in men) have been reported,^{9,10,42,55,70,72} but specific data for ACL injury are lacking.

Ankle injury is almost as frequent as knee injury constituting between 9-22% in men's and 13-26% of the injuries in women's elite football, respectively.^{10,40-42,62,63,68,70,72,78,106,146} The majority of the ankle injuries are sprains representing 7-20% of the injuries in men and 15-19% in women.^{9,10,33,36,40-42,70,72,146} The lateral ligaments of the ankle are most commonly involved due to the well-known inversion injury mechanism.^{5,54}

Finally, the fourth major injury location in the lower extremities is the hip/groin region.^{10,41,42,62,63,68,70,72,78} Hip and groin injuries, sometimes classified exclusively as groin injuries, seems to be more frequent in men's elite football where they constitute between 10-

19% of the injuries compared to only 6-11% in women's elite football.^{10,41,42,62,63,68,70,72,78} In a recent study, the incidence of groin strain was five times higher in male elite footballers compared to their female counterparts.⁷²

Tissue damage or medical attention

When defining injury according to tissue damage or medical attention, the injury pattern is different than in studies defining injury according to time loss. The frequency of contusions, for instance, is considerably higher (35-71%).^{84,85,88} On the other hand, the frequency of thigh injuries is essentially the same as in time loss studies and these injuries seem to affect male (14-20%) and female players (8-22%) to the same extent.^{84,85,88} With these definitions, however, the proportion of knee injury seems to be higher among men (13-23%) than in women (0-11%), but ankle injuries are in contrast slightly more common in women (17-22%) than in men (12-15%).^{84,85,88}

Circumstances of football injury

Injuries can occur without contact or as the result of contact with another player or an object such as the ball, goal post or sideline advertisement board. Two-foot tackles together with clash of heads are the events associated with the highest risk of injury.⁵⁰ The frequency of contact injury depends on the injury definition used. However, even with similar definitions, frequencies vary widely.⁸⁷ A possible explanation to this discrepancy could be that the distinction between contact and non-contact mechanisms is often very difficult.⁹¹ A direct hit to the knee obviously falls into the contact category, but it is not clear how, for instance, a push from behind just before the injury should actually be interpreted.

Nevertheless, 15-29% of all match injuries in men's^{59,61,62,68,72} and 16-19% in women's elite football^{72,78} are the result of foul play as judged by the referee. However, since overuse injury is caused by repetitive micro-trauma, it would probably be fairer to report the foul play figures for traumatic match injuries only. In studies using this approach, foul play has been attributed to account for 18-28% of all traumatic match injuries in men's elite football,^{12,40} while no similar data exist for women. Almost nine of ten foul play injuries have been ascribed to opponent foul.^{59,62}

There is furthermore no consensus in the literature as to when most injuries actually occur during a match. Some studies have reported more injuries in the second than in the first half,^{59,62,63,99} while others have not been able to reproduce these findings.^{10,61,148} Similarly, no differences between the six quarters of a match have been found in some studies,^{3,6,11} whereas increasing number of injuries towards the end of each half has been reported in other studies.^{62,63,84}

Severity of football injury

Injury severity can be classified according to nature of sports injury, duration and nature of treatment, sporting time lost, working time lost, permanent damage, or cost.¹³⁹ Severity is most commonly based primarily on the number of days that have elapsed from the injury to the return to football.^{21,81,89,144}

This classification may at first seem rather simple if the study uses a time loss injury definition. However, the proportion of severe injury depends on the exact definition of time

loss and will thus be higher if two days of absence is required for a countable injury compared to only one day.²¹ This is illustrated when comparing the two studies conducted on similar English professional cohorts that have reported frequencies of 11% (one day) and 23% (two days), respectively.^{62,63} Moreover, some studies have defined a severe injury as more than three weeks of absence,^{4,6,10-13,81} while other studies define it as more than four weeks,^{9,23,28,36,62,63,67,68,70,72,78,84,110,116,145-147} 30 days^{41,42,151} or a month.^{40,85,88,99,106,148} According to the recent consensus paper, a severe football injury is an injury causing more than 28 days of absence from football.⁵³

Most studies on elite football, defining injury as requiring a player to miss one day or one scheduled activity and severe injury as absence more than four weeks/one month,^{36,41,42,62,67,68,70,72,78,106,151} have reported frequencies of severe injury between 9-16% in men and 12-22% in women. The only exception is the small study on three male elite teams in Sweden that found a remarkably high frequency of severe injury (34%).⁴⁰ As seen when comparing all injury incidences in Table 1, the most plausible explanation for this discrepancy is a possible under-reporting of minor injuries in that study.

Consequences of football injury

It has been estimated that around one-tenth of a professional squad is on sick-leave each week because of injury.⁶³ Most injuries are not severe and the players can return to play within a couple of weeks. Sometimes, however, a player is forced to give up his or her career earlier than desired because of injury.^{27,34,125} Even if players can successfully return to play, some injuries (knee injuries in particular) are also associated with a high degree of medical disability⁴⁶ and premature development of osteoarthritis.^{27,97,124,126,138,141} The injuries may also have financial consequences for the players, clubs, insurance companies etc.^{18,29,39,46,73,98} As calculated some years ago, the average primary medical cost worldwide due to football injuries were \$30 billion US dollars per year.²⁹ More recently, the total diagnosis-related group (DRG) cost for all knee surgeries among licensed football players in Stockholm was \$311 000 US dollars in 1997 or around \$15 US dollars per player.⁴⁷ Finally, injuries can also influence the success of a team as evaluated by the final position in the league.¹¹

Risk factors for football injury

A risk factor or hazard can be defined as a condition, object or situation that may be a potential source of harm to a person.⁵¹ Risk factors have typically been divided into intrinsic and extrinsic ones.^{16,107,114,139} Intrinsic or personal risk factors include age, gender, body composition, health, physical fitness, anatomy, previous injury and psychological profile. Extrinsic or environmental risk factors are on the other hand exposure-related factors (type of sport, playing position, level of play, time of season etc.), weather conditions (temperature, relative humidity, wind etc.), equipment (footwear, clothing, playing or protective equipment etc.), surface type (natural grass, gravel, artificial turf etc.) and the rules of the sport (including player adherence and correctness of referee assessment). Until now, intrinsic risk factors have been investigated more often than extrinsic ones.

Historically, most studies have looked at factors such as reduced range of motion (ROM) or poor muscle strength among the individual footballer in their attempt to explain the occurrence of injuries.¹⁰ In recent years, however, some studies at the elite level have investigated the influence of previous injury on future risk of injury.^{10,43,70} In the two studies

on men's elite football, previous injury was not only the strongest risk factor for football injury in general, but also for new groin strain/injury, new hamstring strain/injury and new knee sprain/traumatic knee injury.^{10,70} However, conflicting results were obtained for previous ankle sprain; it was a significant risk factor in the former study,¹⁰ but not in the latter study.⁷⁰ There is also some discrepancy between these two studies and another recent study on women's elite football which showed that neither previous knee sprain nor previous ankle sprain was a significant risk factor for new sprain.⁴³

The effect of age has been investigated in some studies, but these studies have found even more conflicting results.^{10,43,70,72,78,106} Increasing or high age has been associated with a higher risk of injury in male elite footballers,^{10,72} but most studies, including those on women, have reported no age effect.^{43,70,72,78} No other intrinsic factor has been able to explain injury occurrence in general.¹⁰⁷

Prevention of football injury

Despite their importance, there are unfortunately quite few studies that have evaluated preventive measures in football. In a recent review, only eight published studies conducted on football players exclusively were identified in a literature search.⁸⁷ To my knowledge, two published studies were not included in this review,^{94,128} and another four studies have been published or are in press since then.^{13,71,80,100} Five of the fourteen studies on injury prevention are conducted on female players only^{64,100,128,132} or on mixed cohorts.⁸⁰

The first study ever showed an overall injury reduction of 75% with a multi-modal intervention programme in senior male amateurs.³² Multi-modal programmes have also been shown to lower the rate of injury in youth football^{64,83} and recently the rate of ACL injury in female adolescents.¹⁰⁰ One study reduced the re-injury rate in male amateurs with a coach-controlled rehabilitation programme.⁷¹ Another study showed a decrease in the overall injury rate by 30% in a men's college football team after introducing a strength training programme during the preparation period.⁹⁴ Studies have also shown a preventive effect of ankle orthoses among male amateurs with previous ankle sprain^{131,136} as well as among female college players.¹²⁸ In one of the studies, a positive effect on recurrent ankle sprains was also seen for ankle disc training.¹³⁶ Balance board training has been reported to have a preventive effect on ACL injuries among male amateurs,²² but no effect was seen when studying traumatic injuries in the lower extremities among female amateurs.¹³²

Only three of the fourteen studies on football injury prevention have been undertaken in elite players and in fact all of them are Scandinavian.^{13,14,80} The first study showed positive effects of eccentric overload on hamstring injuries,¹⁴ and the second study reported a lower injury frequency with training in mental skills among high-risk players.⁸⁰ In the third study, there was no effect of a video-based injury awareness programme on the rate of traumatic injuries.¹³

AIMS OF THE THESIS

General

- to prospectively study the injury characteristics (incidence, pattern and severity of injury) in Swedish and European top-class football as well as to study risk factors for injury with special emphasis on the ACL injury of the knee

Specific

- to study the injury characteristics in Swedish men's elite football and the influence of two different injury definitions on the apparent risk of injury (*Paper I*)
- to study the prevalence of ACL injury in Swedish men's elite football and the incidence of new knee injury after previous ACL injury (*Paper II*)
- to study the injury characteristics in European men's professional football and the influence of geographic regions and international duty on the risk of injury (*Paper III*)
- to study the injury characteristics in European Championships in football and the influence of gender and age on the risk of injury (*Paper IV*)
- to study the prevalence and incidence of ACL injury in Swedish men's and women's elite football and the influence of gender and age on the risk of injury (*Paper V*)

SUBJECTS

Four main samples were included as seen in Figure 2. The first two samples (*Papers I-III*) consisted of men only and the other two samples (*Papers IV and V*) consisted of both sexes.

Paper I

In the 2001 season, 310 of 312 players from all 14 clubs in the Swedish men's elite league were included; one player did not consent to participate at the start of the study and the second player withdrew his consent after three months. During the study period, 31 players (10%) dropped out; 30 players due to team transfer and one player gave up football because of illness. Mean age was 24.9 ± 4.7 (range 17-38) years.

Paper II

The cohort from *Paper I* was divided into 24 players who had a history of previous ACL injury at the start of the study and 286 players without that history. There was no difference in the mean age between the ACL-injured group and the ACL-healthy group (25.3 ± 4.3 (range 17-32) years vs. 24.8 ± 4.8 (range 17-38) years, $p=0.62$).

Paper III

In the 2001-2002 season, 266 of 269 players from 11 clubs of the men's elite leagues in five European countries were included; two players did not consent to participate at the start of the study and one player withdrew his consent after two months. Thirty players (11%), all due to team transfer, dropped out during the season. Mean age was 25.7 ± 4.4 (range 17-38) years.

Paper IV

During 2004 and 2005, the national teams of three UEFA European Championships were studied. In total, 368 players in the men's tournament, 160 players in the women's tournament and 144 players in the men's U-19 tournament were included. No player denied participation or dropped out. The players' mean age was higher in the men's championship than in the women's championship (27.2 ± 3.7 (range 18-36) years vs. 24.8 ± 3.8 (range 16-36) years, $p<0.0001$, *unpublished results*). The mean age in the U-19 championship was 18.5 ± 0.6 (range 16-19) years.

Paper V

In the 2005 season, 467 Swedish elite players from all 12 clubs in the women's elite league and 11 clubs in the men's elite league were included. Three other clubs in the men's elite league (68 players) withdrew their consent early during the season and were excluded. All other players consented to participate, but 42 players (9%) dropped out during the season; 16 players in the women's league (10 due to team transfer and 6 due to social or other reasons) and 26 players in the men's league (all due to team transfer). The mean age was higher in the men's league than in the women's league (24.5 ± 4.7 (range 16-37) years vs. 23.0 ± 4.1 (range 15-41) years, $p<0.001$).

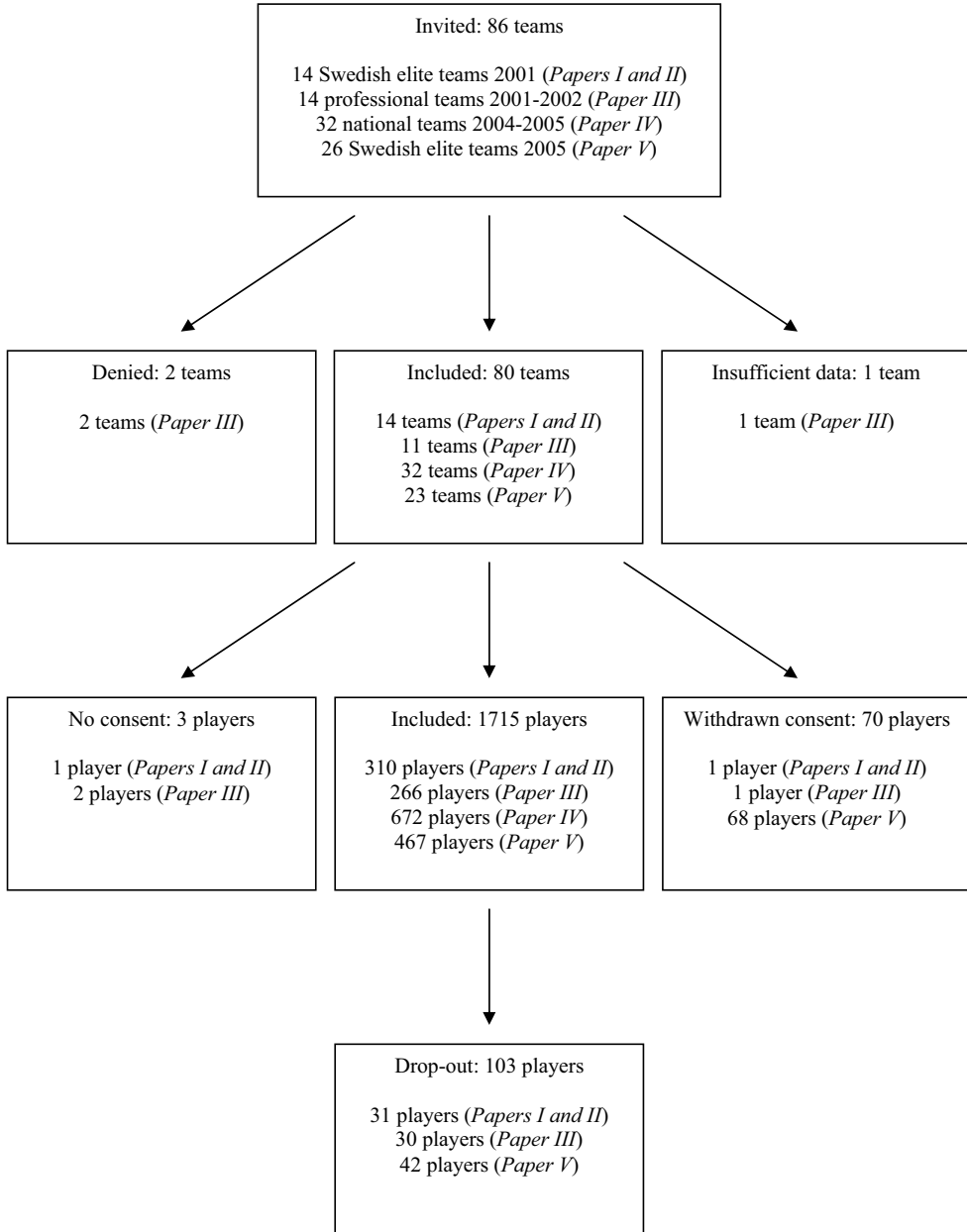


Figure 2. Flowchart of football players eligible for and included in Papers I-V.

METHODS

Before each study, all teams involved received both verbal and written information from the research group.^{69,103} This included a specific study manual containing examples of how to fill in the different study forms. The full seasons (pre-season and competitive season) or championships (opening to final match) were studied. In *Papers I, II and V*, the season consisted of pre-season (January to March) and competitive season (April to October). In *Paper III*, the season consisted of pre-season (July to August) and competitive season (September to June).

Inclusion criteria

All licensed players belonging to the first team squads during the first month of the season were asked to participate in *Papers I-III and V*. In *Paper IV*, all national team players listed in the squads on the day of the opening match in the championships were invited. Players injured at the start of each study were included, but current injury was not taken into account.^{53,69} Data from players dropping out were included for the players' entire time of participation.^{33,53,69,103} Players joining the teams after the first month of the season or after the opening match of a championship were not included. No other exclusion criteria were applied.

Study forms

Three standard study forms were routinely used in all papers: (1) the baseline form (Appendix A), (2) the exposure form (Appendix B), and (3) the injury form (Appendix C).^{53,69,103} The baseline form was completed during the first month of the season in *Papers I-III and V* or before the opening match of the championship in *Paper IV*. Age data and leg dominance were filled in by the player or a medical practitioner. Previous major injuries and surgery were reported by the practitioner. During the study period, individual exposure to all training sessions and matches in minutes was documented prospectively on the exposure form. Attendance was completed on a daily basis and was filled in by one of the coaches or a member of the medical staff as preferred by the team. In addition, individual match exposure was taken from the official match records in *Paper IV*. In *Papers I-III and V*, a member of the club medical staff filled in the injury form immediately after the event while the national team physician completed the form in *Paper IV*. The forms were delivered monthly in *Papers I-III and V* and around every third day in *Paper IV*. When the research group received the study forms, they were immediately checked by the investigators for any missing or unclear data. Feedback was sent to the recorders after each return of the forms.^{53,69} All injuries were given a specific injury diagnosis according to a modified Orchard Sports Injury Classification System (OSICS).¹¹³

In *Paper V*, the team physician and/or the team physical therapist was contacted to complete a standard ACL injury form after each prospectively recorded ACL injury. Copies of the medical records were requested. The ACL-injured players were asked to fill in the Knee injury and Osteoarthritis Outcome Score (KOOS)^{121,122} as soon as possible after their ACL injury. After players' return to football, they were asked once again to complete the KOOS questionnaire. KOOS is a patient-relevant and self-administered outcome measure with five separate dimensions: pain, other symptoms, activities of daily life, sport/recreation function and knee-related quality of life. The score for each dimension is transformed to a 0-100 scale

where 100 represents no knee problems at all. The reported ACL injuries in *Paper II* (at baseline) and in *Paper V* (during the season) were matched with the files from the insurance company (Folksam) associated with the mandatory playing licence.

Definitions

A training session was defined as any coach-directed physical activity carried out with the team in *Papers I-III*, and as team-based and individual physical activities under the control or guidance of the team's coaching or fitness staff aiming at maintaining or improving player's football skills or physical condition in *Papers IV and V*. A match was defined as any scheduled friendly or competitive match with the club (first, second and youth teams) or with a national team. Time loss injury was defined as an incident occurring during scheduled training sessions or matches causing the player to miss the next training session or match.^{30,69} In *Paper I*, tissue injury was defined as any tissue damage caused by football regardless of subsequent absence from matches or training sessions.⁸¹ Traumatic injuries were characterised by acute onset and subdivided into strains, sprains, joint injuries, contusions, fractures, dislocations and other forms of traumatic injury such as wounds and concussions. ACL injury was defined as a partial or total rupture of the ligament occurring either isolated or associated with other injuries to the knee joint. Overuse injury was characterised by insidious onset without any known trauma and specifically defined as a pain syndrome of the musculoskeletal system without any known trauma or disease that might have given previous symptoms in *Papers I and III*.¹¹² In *Paper IV*, overuse injury was defined as being caused by repeated micro-trauma without a single, identifiable event.⁵³ A recurrent injury was defined as the same type of injury to the same side and location within two months of the final rehabilitation day of the previous injury in *Papers I and III*.⁶⁹ In *Paper II*, a recurrence was defined as a subsequent injury of the same type and location and occurring on the same side as the previous injury during the season. In *Paper IV*, a recurrent injury was defined as an injury of the same type and at the same site as an index injury occurring after a player's return to full participation from the index injury.⁵³

Each injury was followed until the final date of rehabilitation. A player was considered injured until the medical staff allowed full participation in all types of training or match play.^{53,69} Injury severity was defined as the number of days that have elapsed from the date of injury to the date of return to full participation in team training and availability for match selection.^{53,69} In *Papers I-III*, the injuries were classified into four categories of severity: slight (1-3 days), minor (4-7 days), moderate (8-28 days) and major (>28 days).⁶⁹ In *Paper IV*, the injuries were classified into six categories: slight (0 days), minimal (1-3 days), mild (4-7 days), moderate (8-28 days), severe (>28 days), and career-ending.⁵³ Foul play was defined as violation of the laws of the game according to the referee. The preferred kicking leg was regarded as the dominant leg and players were classified as right-footed, left-footed or ambidextrous.

STATISTICS AND ETHICS

Statistical methods

Statview® (version 5.0.1, SAS Institute Inc., Cary, North Carolina, USA) for personal computers was used in all papers. All statistical analyses were two-sided and the significance level was set at 5% ($p < 0.05$). No drop-out analysis was performed, since the drop-out frequency was low (103/1715, 6%) and all players were included during their entire time of participation. The statistical methods used are summarised in Table 4.

Table 4. Statistical methods used in Papers I-V.

Statistical method	Paper I	Paper II	Paper III	Paper IV	Paper V
Descriptive statistics					
Anthropometrics					
- Unpaired t-test		X			X
- ANOVA	X		X	X*	
Analytic statistics					
Between group comparisons					
- Chi-square test or Fisher's exact test	X	X	X	X	X
- Mann-Whitney U test	X	X	X	X	X
- Kruskal-Wallis test				X	
- Unpaired t-test		X			
- ANOVA				X	
- Rate ratio					X
Within group comparisons					
- Wilcoxon signed rank test	X	X	X	X	X
- Rate ratio					X
Survival analysis					
- Cox proportional hazards		X			X

* *Unpublished results*

Anthropometrics

Anthropometric data were normally distributed. Team differences in *Papers I and III* were therefore analysed using a one-way factorial analysis of variance (ANOVA) as well as differences between the tournaments in *Paper IV*. Group differences in *Papers II and V* were analysed with an unpaired t-test.

Exposure

Exposure was calculated on an individual level and expressed as the number of playing hours. Group differences in exposure were analysed using an unpaired t-test in *Paper II* and the one-

way factorial ANOVA in *Paper IV* due to normally distributed exposure data. Differences in training/match-ratios in *Paper I* were analysed using the Wilcoxon signed rank test.

Injury incidence

Injury incidence was calculated on a team level according to the formula $I=A/R$, where A is the number of injuries sustained during the study period and R is the sum of the individual exposure times. The incidence per 1000 exposure hours is reported and expressed as mean with the corresponding standard deviation (SD). Injury incidences were in general not normally distributed and differences in *Papers I-IV* were therefore analysed using non-parametric tests. In *Paper V*, ACL injury incidences were analysed using a rate ratio (RR) with the corresponding 95% confidence interval (95% CI).

Injury prevalence

The ACL injury prevalence in *Papers II and V* was calculated as the percentage of first team squad players who had a history of previous ACL injury in January 2001 and 2005, respectively.

Injury severity

The severity of index injuries and re-injuries in *Papers I and III* was not normally distributed and differences between them were analysed using the Wilcoxon signed rank test.

Foul play

Foul play comparisons in *Papers I and IV* were analysed using the chi-square test or the Fisher's exact test.

Survival analyses

The incidence of new knee injury after previous ACL injury in *Paper II* was analysed using a Cox proportional hazards regression model as well as the effect from age on the incidence of ACL injury in *Paper V*. The relative risk is expressed as a hazard ratio (HR) with the corresponding 95% CI. Both the player and the knee were used as the unit of analysis in *Paper II*.

Ethics

Papers I, II and V were all approved by the Ethics Committee of Linköping University, Sweden (# 01-062, # 03-504, # 73-04). *Papers III and IV* were approved by UEFA. Signed informed consent according to the declaration of Helsinki was obtained from all participating players. The consent could be withdrawn at any time during the study without specifying the reason. All collected data were treated confidentially.

RESULTS

The main results from *Papers I, III and IV* are summarised in Tables 5-8, respectively.

Table 5. Injury types as reported in Papers I (n=715), III (n=658) and IV (n=80).

Study	Sprain	Strain	Contusion	Fracture	Dislocation	Other	Overuse
<i>Paper I</i>	116 (16%)	158 (22%)	122 (17%)	20 (3%)	6 (1%)	33 (5%)	262 (37%)
<i>Paper III</i>	152 (23%)	169 (26%)	105 (16%)	16 (2%)	6 (1%)	31 (5%)	179 (27%)
<i>Paper IV</i>	18 (23%)	20 (25%)	23 (29%)	4 (5%)	0 (0%)	7 (9%)	8 (10%)

Table 6. Injury locations as reported in Papers I (n=715), III (n=658) and IV (n=80).

Study	Hip/groin	Thigh	Knee	Lower leg	Ankle	Foot	Other
<i>Paper I</i>	114 (16%)	165 (23%)	111 (16%)	109 (15%)	73 (10%)	53 (7%)	90 (13%)
<i>Paper III</i>	79 (12%)	152 (23%)	131 (20%)	73 (11%)	89 (13%)	35 (5%)	99 (15%)
<i>Paper IV</i>	7 (9%)	17 (21%)	11 (14%)	10 (13%)	15 (19%)	10 (13%)	10 (13%)

Table 7. Injury severity as reported in Papers I (n=715), III (n=658) and IV (n=80).

Study	<4 days	4-7 days	8-28 days	>28 days
<i>Paper I</i>	232 (32%)	196 (27%)	220 (31%)	67 (9%)
<i>Paper III</i>	182 (28%)	186 (28%)	193 (29%)	97 (15%)
<i>Paper IV</i>	40 (50%)	9 (11%)	15 (19%)	16 (20%)

Table 8. Time loss injury incidence (number of injuries per 1000 hours) as reported in Papers I, III and IV.

Study	Study period	Population	Match	Training
<i>Paper I</i>	1 full Swedish season 2001	14/14 division I teams	25.9	5.2
<i>Paper III</i>	1 full European season 2001-2002	11 division I teams	30.5	5.8
<i>Paper IV</i>	Men's European Championship 2004	16/16 national teams	36.0	2.1
	Women's European Championship 2005	8/8 national teams	36.0	2.5
	Men's U-19 European Championship 2005	8/8 national teams	30.4	2.9

Paper I

A total of 77% of the players incurred 765 tissue injuries and 715 time loss injuries. There were no differences in injury incidence between tissue injury and time loss injury during match play (27.2 ± 17.0 vs. 25.9 ± 16.0 injuries per 1000 hours, $p=0.66$) or during training (5.7 ± 3.7 vs. 5.2 ± 3.2 injuries per 1000 hours, $p=0.65$).

The time loss injury types and locations are shown in Tables 5 and 6, respectively. The most frequent injury was the thigh strain representing 14% of injuries. The knee was the most frequent location of severe injury (36%). Injury severity is shown in Table 7. Re-injury constituted 22% of all injuries. The re-injuries had significantly longer absence than the index injuries (10.9 ± 15.1 vs. 7.6 ± 7.1 days, $p=0.02$). Twenty per-cent of the match injuries were due to foul play.

The training/match-ratio was significantly higher during the pre-season compared to the competitive season (8.7 ± 1.9 vs. 5.1 ± 0.8 , $p=0.001$). The incidences of training injury (8.0 ± 4.9 vs. 3.7 ± 2.3 injuries per 1000 training hours, $p=0.001$), overuse injury (4.2 ± 2.9 vs. 2.1 ± 2.2 , $p<0.01$) and re-injury (2.7 ± 3.0 vs. 1.3 ± 1.2 , $p=0.02$) were all higher during the pre-season.

Paper II

At the start of the study, 8% of the players had a medical history of previous ACL injury. Except for the bilateral injuries of one player, the rest of the ACL injuries had all been treated with ligament reconstruction. All but one previous ACL injury were identified in the files of the insurance company associated with the playing licence.

Players with a history of previous ACL injury had a significantly higher incidence of new knee injury during the season than those without (4.2 ± 3.7 vs. 1.0 ± 0.7 injuries per 1000 hours, $p=0.02$). There was no difference in the incidence of lower limb injuries not related to the knee (5.4 ± 6.0 vs. 5.7 ± 3.6 injuries per 1000 hours, $p=0.66$). Using the player as the unit of analysis (24 vs. 286 players), the incidence of new knee injury was significantly higher among the players with a history of previous ACL injury (HR 3.4, 95% CI 1.8-6.3). Similarly, using the knee as the unit of analysis (27 vs. 593 knees), the incidence of new knee injury was also significantly higher (HR 4.5, 95% CI 2.3-8.8). Ten players were ACL reconstructed during the preceding season and half of these players suffered new injury to their reconstructed knee.

Paper III

A total of 85% of the players incurred 658 time loss injuries. The injury incidences are shown in Table 8. There were no differences in injury incidence between the pre-season and the competitive season. The match injury incidence among the four English and Dutch teams was significantly higher than for the seven Mediterranean teams (41.8 ± 3.3 vs. 24.0 ± 7.9 injuries per 1000 exposure hours, $p=0.008$) as well as the incidence of severe injury (2.0 ± 0.5 vs. 1.1 ± 0.6 injuries per 1000 exposure hours, $p=0.04$).

Players with international duty during the season (56%) participated in more matches than the rest of the players (42 ± 15 vs. 28 ± 15 , $p<0.001$). There was no difference in the amount of

training (176 ± 46 vs. 171 ± 61 , $p=0.79$), but a tendency towards a lower training injury incidence among the players with international duty compared to those without (4.1 ± 2.4 vs. 6.2 ± 2.7 injuries per 1000 hours, $p=0.051$). Three per-cent of all injuries occurred during international duty.

The injury types and locations are shown in Tables 5 and 6, respectively. The most common injury was thigh strain constituting 16% of all injuries. Posterior thigh strains were significantly more common than anterior ones (67 vs. 36 injuries, $p<0.0001$). One-third of the severe injuries were located to the knee. Injury severity is shown in Table 7. Re-injury constituted 15% of all injuries. Re-injuries did not have a longer absence than the index injuries (12.4 ± 22.1 vs. 13.0 ± 21.2 days, $p=0.95$). Twenty-three per-cent of the match injuries were due to foul play.

Paper IV

A significantly higher number of training sessions per group stage week was found in the women's European Championship 2005 compared to the men's European Championship 2004 and the men's U-19 European Championship (6.3 ± 1.0 vs. 4.1 ± 0.6 and 4.3 ± 1.0 , $p<0.0001$). In total, 11% of the players incurred 80 injuries. The injury incidence was 34.6 ± 32.8 injuries per 1000 match hours and 2.4 ± 4.7 injuries per 1000 training hours. The injury incidences in each championship are shown in Table 8. There were no significant differences between the tournaments. Teams eliminated after the group stage in the women's championship had a significantly higher match injury incidence compared to the teams that went to the semi-finals (65.4 ± 34.3 injuries per 1000 match hours vs. 5.0 ± 10.1 injuries per 1000 match hours, $p=0.021$).

There was no difference in the number of injuries during match play between the first and second halves (26 vs. 25 injuries, $p=0.69$). Non-contact mechanisms were ascribed to 41% of the match injuries and a significantly higher frequency of non-contact injury was seen in the second half (71% vs. 41%, $p=0.049$). One-fifth of all injuries were severe. There were no differences in injury severity between the tournaments. Foul play caused 30% of all traumatic match injuries.

Paper V

At the start of the study, the prevalence of a history of previous ACL injury in the Swedish men's and women's elite leagues 2005 was three times higher among female players (15% vs. 5%, $p=0.0002$). During the season, 16 new ACL injuries were recorded. The ACL injury incidence was significantly higher during match play than during training (0.66 ACL injuries per 1000 match hours vs. 0.05 ACL injuries per 1000 training hours; RR 14.3, 95% CI 5.0-41.2). No gender-related difference in ACL injury incidence was seen (HR 1.2 women vs. men, 95% CI 0.44-3.1). Since the age at injury was lower in the females (20 ± 2 years vs. 24 ± 5 years, $p=0.069$), this ratio was even lower after adjustment for age (HR 0.99, 95% CI 0.37-2.6). Age was associated with ACL injury incidence amongst women where the risk decreased by 24% for each year increase in age (HR 0.76, 95% CI 0.59-0.96). No such association was seen in men (HR 0.95, 95% CI 0.82-1.1).

The mean time to confirmed diagnosis was 19 ± 13 days in women and 9 ± 11 days in men ($p=0.06$). Fourteen ACL injuries underwent ACL reconstruction. Time to reconstruction

varied widely amongst the women (range 4-345 days), but not the men (range 24-63 days). At a follow-up in the beginning of 2007, twelve of the reconstructed players had returned to football. Nine players had returned to the same playing level as before the injury. Two females were still under rehabilitation and had both undergone arthroscopy twice due to cyclops syndrome. All seven reconstructed men had returned to play, but three players sustained new injuries in their reconstructed knees during 2006 and a fourth player suffered a contralateral ACL tear.

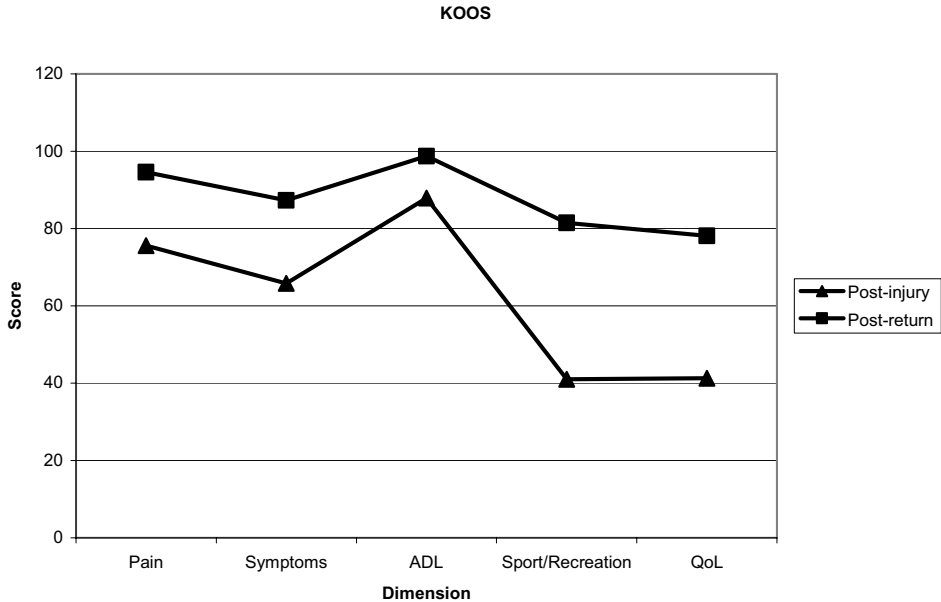


Figure 3. KOOS reported for ACL reconstructed elite football players in Sweden after ACL injury during 2005 and after return to football (n=10).

Fully completed post-injury and post-return KOOS questionnaires were obtained for ten of the thirteen players who had returned to play after ACL injury. No gender-related difference was seen for any dimension and the scores are therefore shown together in Figure 3. Significant improvement after ACL reconstruction was seen for all five dimensions: pain (75.6 ± 17.1 vs. 94.6 ± 7.1 , $p=0.019$), other symptoms (65.8 ± 20.5 vs. 87.3 ± 10.3 , $p=0.047$), activities of daily living (87.9 ± 13.4 vs. 98.7 ± 1.9 , $p=0.022$), sports/recreation function (41.0 ± 33.0 vs. 81.5 ± 7.1 , $p=0.015$) and knee-related quality of life (41.3 ± 29.8 vs. 78.1 ± 12.9 , $p=0.021$). Thirteen ACL injuries had been reported to the insurance company associated with the playing licence one year after the end of the season.

DISCUSSION

Sports injury surveillance

Several authors have repeatedly discussed the difficulties in comparing studies because of the lack of methodological consensus.^{21,26,29,35,65,69,74,81,89,111,139} Clearly, meaningful comparisons of exposure and injury epidemiology can only be made between studies with essentially the same study design, definitions and methods. Until now, however, methodological differences between the studies may have been greater than the reported differences in their results. Some form of golden standard method has thus been needed for a long time and last year a consensus statement for football injury research was finally published.⁵³

The research project which this thesis is based on was developed during 1999-2000 and was validated according to the principles previously outlined for Canadian intercollegiate football.¹⁰³ A comprehensive literature review was followed by a consensus discussion within the UEFA Medical Committee about the proper design of an injury surveillance study on elite football.^{35,69} The project was introduced 2001 in studies of the men's elite leagues in Sweden (*Paper I*) and Denmark.⁶⁸ After feedback from the involved clubs, some minor revisions in the methodology were made, for instance making an exact diagnosis mandatory on the injury form, before the start of the study on European professional football (*Paper III*).

The papers in the present thesis were all designed and the data were collected before the recent joint consensus statement was published.⁵³ However, the UEFA methodology already fulfilled most of the items in this consensus paper. It was therefore possible to report the findings reported in *papers IV and V* in almost full agreement to these guidelines. *Papers IV and V* therefore differ in the exact definitions of overuse, recurrence and severity compared to *Papers I-III*. However, the differences are minimal, sometimes only semantic, and should have no practical influence on the results of this thesis.

Injury definition

Several definitions of what constitutes a sports injury exist in the literature.^{29,74,81,144} From now on, football injury should be defined as any physical complaint sustained by a player that results from a football match or football training, but with two reporting levels: time loss or medical attention.⁵³

Time loss injury

Historically, injury definitions based on time loss seem to be most widely used in football.^{35,69,74,81,89} Documenting time loss is usually very easy and attractive for recorders. There are, however, certain limitations to this definition,^{81,89,111} although most arguments will affect youth and amateur football more than elite football:

- It is sport-specific as illustrated by the example of a broken finger

This injury would not necessarily prevent an outfield player from playing football, but it would probably prevent someone from playing ice hockey or team handball. The primary objective of most sports injury surveillance is, however, to describe and compare the injury characteristics within a certain sport and not between different sports.

- It depends on the frequency of training sessions and matches

In youth or amateur football, the teams will usually have only one to three training sessions a week in contrast to almost daily activities at the elite level. An incident may therefore heal in the interval between two distant sessions and thus being excluded from the injury statistics.⁷² However, injury assessment in future studies should be independent of whether a training session actually takes place on the day after the injury or whether a player is selected to play in the next match.⁵³

- The availability of medical treatment influences time loss

Most elite teams have a defined club medical staff, but medical support is usually completely absent at a lower level of play. This factor is therefore important to consider when comparing youth or amateur football with elite football.

- The importance of a match or an individual player may influence participation

If a club has a medical staff, these practitioners usually have the mandate to decide when a player is available for play. At lower playing levels, however, it may be possible that the coach selects a player to play in an important match even if he or she still has serious complaints. There is of course also a risk that a player will not report any complaint to the coach or the medical staff if he or she really wants to play an important match.

- It is possible for an injured player to participate, but with a modified exercise programme

Elite players are usually considered injured until they are able to comply fully with all instructions given by the coach¹⁰⁻¹³ or until clearance has been obtained from the club medical staff to participate in training without restrictions and be available for match selection.^{37,68,70} All exercises before this date are considered as part of rehabilitation and professional players are usually on sick-leave until full participation in team training is allowed.

Defining injury according to time loss varies in the literature from requiring the player to miss at least one training session or match,^{9-11,40-41,72,78,80,110,143,151} the next training session or match,^{12,14,33,36,37,67,68,70,117} the next day,^{3,4,6,13,28,42,43,62} or the next two days.^{63,95,145-147} One problem when defining injury as missing the next scheduled activity or the next day(s) is that a player may sometimes sustain an injury one day but does not have to rest until a few sessions or days later. In this thesis, there are a few examples where a player sustaining injury during a match was able to participate fully in a low-intensity recovery session the following day, but could not participate fully in high-intensity exercises two days after the incident. This dilemma is now completely solved, since the consensus paper defines a time loss injury as an “injury that results in a player being unable to take full part in future football training or match play”.⁵³ In this context, the term future refers to any time after the onset of the injury, including the day of injury.

Tissue injury

With the aim of avoiding the limitations of the time loss injury definition, it has been advocated that an anatomical tissue diagnosis should be used instead.⁸¹ Such a definition refers to any tissue damage or physical complaint caused by football regardless of subsequent

absence from matches or training sessions. Comparisons between different sports are made easier with this definition, since it is not sport-specific. However, the tissue injury definition is also associated with certain limitations:

- Physical contacts, tackles and duels are a natural part of football

It could be difficult to demarcate these contacts from tissue injuries and carried to an extreme, a qualified medical practitioner would have to routinely examine all players after each activity. This approach would be both impossible and impractical in most environments. Even at the highest level, only around 3-4% of all tackles usually lead to on-pitch medical attention and another 2-3% after the match.⁵⁰

- Complaints without objective signs of tissue damage could confuse the injury recorder

Pain threshold almost certainly differs between players and it could be argued that it would be necessary to examine these players further with, for instance, ultrasound or MRI to be able to verify the exact location of any tissue damage.

- The availability of medical treatment influences tissue damage

Theoretically, it would be more important to have the clinical examinations performed without delay than with time loss, since minor tissue damage may heal rapidly. Weekly visits by the study physicians^{23,81,116} may not therefore be enough to ensure reliable data collection. Furthermore, a qualified medical practitioner is the only person who can evaluate the true nature and extent of tissue damage, also making this definition less suitable at lower playing levels where medical support is absent.

In *Paper I*, the club medical staffs were carefully informed on how to record injuries with two separate filters; tissue injuries and time loss injuries. However, there were only 50 other tissue injuries recorded in addition to the 715 injuries resulting in time loss. Consequently, no difference in injury incidence between the two levels of defining injury could be found. The most plausible explanation is that the clubs had almost daily scheduled activities throughout the season, resulting in a high probability for a player not being able to participate fully on the day following an injury. Whether the result had been different in a similar study on amateur football because of fewer training sessions in that environment is unclear. Another possible explanation is the high frequency of overuse injury found. Overuse injuries constituted more than one-third of all injuries and these complaints were almost always associated with absence from the pitch sooner or later during the season. The initially reported tissue injury was thus converted to a time loss injury sooner or later when the player was not able to participate anymore. Finally, some under-reporting of contusions cannot be fully ruled out. There was a frequent impression among recorders that players who obviously had been involved in many contact situations did not complain or seek medical attention afterwards. Where the filter should be put exactly is not clear from the literature.^{81,116} No instructions from the study group were given to the practitioners to routinely interview or examine all players after each activity, but such an approach may have increased the number of tissue injuries reported. Interestingly, there was no single injury reported due to delayed onset muscle soreness (DOMS) suggesting that such complaints are considered as “normal overload” by the clubs.

Medical attention injury

A medical attention injury denotes any physical complaint receiving medical attention from the team physician or other medical practitioner regardless of the consequences with respect to tissue damage or time loss. Such a definition has been used recently in some studies on international or professional football.^{49,55,84,88,106} This definition is completely dependent on adequate medical support from club medical staff or study practitioners. It takes a qualified practitioner to evaluate any tissue damage properly and, in my opinion, there is no decisive difference between tissue injury and medical attention injury. In addition, the studies on the FIFA international championships seem to regard the definitions as interchangeable.^{84,85,88} It should, however, be noted that the threshold for seeking medical advice may differ between players in spite of similar objective complaints.

Hospital-treated or insurance claims injury

In the Nordic countries, 10-17% of all injuries treated at emergency departments result from participation in sports.^{73,98,149} In another study, 17% of the acute visits to all clinics in a Swedish municipality were due to sports or physical exercise.²⁵ Football-related injuries constituted 35-45% of all sports injuries in these studies. However, studies using this design usually reflect only the popularity of the sport and not the actual risk of injury, since the population at risk is unknown.⁸¹ Analysing the data from medical records, or from insurance company files, implies that every player is equally exposed to injury which is normally not the case. There is also a well-known bias towards acute and severe injuries such as ligament rupture or fracture (the so called “tip-of-the-iceberg” phenomenon).^{74,139} This bias is clearly illustrated in studies that have reported their results based on insurance claims data,^{39,46} since these incidences are much lower than the figures usually reported in prospective studies in the field.

Since most elite clubs have access to medical support on a daily or regular basis, relatively fewer injuries may require hospital admission compared to lower level of play. The validity of a design using hospital records when studying injuries in elite football can therefore be seriously questioned and no such study exists to my knowledge. In contrast, it could be possible that the club medical staff may ensure that relatively more injuries, especially severe injuries, are reported to the insurance company compared to the amateur level. All Swedish players from the age of 15 carry insurance in the same company associated with the mandatory playing licence similar to other Nordic countries. In *Paper II*, all but one of the previous ACL injuries were identified in the insurance company files. In a similar study on the women's elite league in Sweden 2004, however, only 40 of 47 previous ACL injuries were reported to the insurance company.¹⁴² In *Paper V*, only 13 of 16 ACL injuries occurring during the 2005 season had been reported to the insurance company one year after the end of the study. Even if a majority of ACL-injured players was identified in the files, a variable number were missing and the validity of insurance claims data is thus not optimal in this respect.

Exposure and injury incidence

The importance of collecting exposure data has been emphasised in several studies.^{21,26,96,111} To be able to know the actual injury incidence, it is important not only to collect some exposure data, but also to record it adequately. Injury incidence can be calculated at the individual, team or league level,⁷⁹ although these details are rarely presented in study reports.

Since the players within a team are not independent it has been recommended by some authors that injury incidence should preferably be calculated at the team level, at least when many teams are included in a study.^{33,75} Similarly, exposure can be collected on a team or individual basis depending on the purpose of the study.⁵³ Historically, studies have made some approximation or estimation of exposure by multiplying the number of players by the hours of average participation and the length of the study period.^{33,55,62,67,78,84,85,88,106,148} This approach usually results in an underestimation of the injury incidence, since the exposure loss of players not completing a full training session is not accounted for. It may, however, also be possible that the incidence is sometimes overestimated if, for instance, no consideration is taken to international duty exposure in studies at a higher level of play.³³ National team exposure should therefore be included in those studies where a significant number of players are exposed to international duties.^{69,78,145} In *Paper III*, 56% of all players were exposed to a youth or senior national team during the studied season and the corresponding figure in *Paper I* was 19% of all players (*unpublished results*).

Match exposure is probably easier to record on a team basis, although the exposure loss for players being suspended, sent-off or injured could be potential sources of error. Collecting the official match records from the international, national or local FA, would therefore be an excellent alternative. These records were collected in *Paper IV* as was done in some previous studies.^{10,11,13,143} The match records may be used as a source of external validation and could also reduce the burden of the recorders, since the most successful European clubs play many matches in the Champions League or UEFA Cup in addition to their national league and cup matches. Many top-class players are also exposed to international duty on several occasions during a playing season. It was therefore worrying when a second group stage was added to the Champions League during the 1999-2000 season. Many speculated that this increase in match exposure would be associated with an increased risk of injury. The winner of the Champions League 2001-2002, Real Madrid, played as many as 76 friendly and competitive matches as reported in *Paper III*. However, the mean number of matches per player in the study was only 36 and thus considerably lower than the overall number of matches for the clubs. Injury is the most obvious reason for a player being unavailable for match selection, but illness and suspension are other major causes.¹¹⁵ It is also well-known that the most successful clubs have very large and homogenous squads allowing them to change line-ups regularly and thereby rest players at risk of over-matching. However, not surprisingly, players selected for international duty had a higher match exposure than the rest of the players in *Paper III* and one international player even participated in as many as 69 matches during the season.

Data collection

Retrospective studies are known to be associated with significant recall bias.^{53,81} For example, when a prospective design was compared with a retrospective design in a study on various levels of play in the Czech Republic, it was found that only one-third of all injuries were reported in the retrospective questionnaire after the season.⁸¹ Perhaps even more remarkable was that a quarter of severe injuries had not been reported correctly at the end of the study period. All papers in this thesis were prospective, but even so, the most important consideration in epidemiological studies where many observers are involved is that data are collected in a consistent fashion. A specific instruction manual was therefore distributed to all teams participating;^{69,103} the manual contained basic examples of how to fill in the study forms and highlighting various scenarios where it may be difficult to know how to complete

the forms correctly. When completed study forms were received by the research group, they were immediately checked by the investigators for any missing or unclear data. Regular feedback was sent to the recorders as soon as possible ensuring that all missing or unclear data were clarified.

The injury form should be completed by a medical professional,⁵³ but there is no consensus as to which practitioner is the optimal injury recorder. Heterogeneity of club medical staff where many different practitioners are involved is common, but no study has reported intra- or inter-rater reliability between different recorders in football. To my knowledge, this has been investigated in only one study on sports injuries.¹⁰¹ In that study on rugby union, an expert panel reached consensus in how to classify five videotaped injuries. Ten independent raters thereafter viewed videotaped injuries three times over a period of five weeks and completed an injury report form for each injury at each viewing. The intra- and inter-rater reliability were both 98%, but some necessary details remained unclear from this study. First, the education, occupation and experience of the raters used were not described properly. Second, it is possible that the videotaped injuries consisted of five common traumatic injuries involving a well-known and typical injury mechanism. It may, however, be more difficult to classify insidious overuse complaints or to decide for instance whether an incident is to be regarded as a simple head contusion or a cerebral concussion.

In *Papers I and II*, injuries were diagnosed by a member of the club medical staff (team physician together with a physical therapist and/or naprapath) while the injuries in *Papers III-V* were diagnosed or supervised by the team physician in each case. No analysis of the reliability of medical practitioners involved was, however, made with respect to the classification of injuries. In a few studies, injuries have been given a specific injury diagnosis according to some form of classification system. The two major systems are the International Classification of Diseases (ICD-10)^{81,116} and the Orchard Sports Injury Classification System (OSICS).^{4,6} Since it has been argued that the ICD-10 is too blunt when diagnosing sports injuries,^{65,96,113} a modified OSICS was used in the present thesis. It should, however, be noted that both systems are associated with certain weakness in reliability.¹¹⁸ Clearly, a future challenge is to create a valid and reliable classification system for football injuries.

Risk of football injury

The percentage of players injured during a full playing season was 77% and 85% in *Papers I and III*, which is consistent with other studies on men's elite or professional football (73-81%).^{40,63,68,70,72}

Match injury incidence

It is well-known that match injury incidence seems to increase with level of play. This notion is highly supported by the injury rates found in the present thesis; 25.9 injuries per 1000 match hours in Swedish male elite football players (*Paper I*), 30.5 injuries per 1000 match hours in European male top-class professional football players (*Paper III*), and 36.0 injuries per 1000 match hours in the men's European Championship (*Paper IV*). The match injury incidences in *Papers I and III* are consistent to the time loss rates reported previously as shown in Table 1. Moreover, the incidence in *Paper IV* (34.6 injuries per 1000 match hours) is also very similar to the average expected time loss rate of 35 injuries per 1000 match hours in eight international FIFA tournaments during 1998-2001.⁸⁵ More specifically, the match injury incidence in the men's U-19 European Championship (30.4 injuries per 1000 match

hours) was slightly lower than the expected time loss rates of 33 and 36 injuries per 1000 match hours found in the men's U-17 and the men's U-20 World Championships 2001, respectively.⁸⁵ Likewise, the expected time loss injury rate was somewhat higher in the men's World Cup 2002 (51 injuries per 1000 match hours)⁸⁴ than in the men's European Championship 2004.

No difference was seen between the men's and women's European Championships in *Paper IV* which agrees well to recent findings from the Olympic Games 2004.⁸⁸ In the Olympic Games 2000, however, the expected time loss rate was twice as high among men.⁸⁵ The main difference between the FIFA studies and *Paper IV* is that the team physician had to decide immediately at the end of the match whether the incident would result in future time loss according to former studies, but the reported incidences are based on true time loss in *Paper IV*. Consequently, the most plausible explanation for the slightly higher figures found in the FIFA studies is that it was difficult to decide at the end of the match whether an injury would result in time loss.

Another interesting finding in *Paper IV* was that the teams eliminated in the women's European Championship had a significantly higher match injury incidence than the teams that went to the final stage. No difference was found in the men's senior and men's U-19 European Championships. This suggests that injuries may have a greater impact on a team's success in women's football. First, injury may have a direct influence on the match result, since the best players are selected to play and the team is weakened if a player is injured. Second, injury may have an indirect impact on the match result, since tactics are disturbed if a player in the initial line-up is substituted because of injury. Third, teams qualifying to the final stage may have been in better physical condition. Fourth, teams that are more dependent on the health status of their key players may be less likely to rest these players even if they have physical complaints or are fatigued.

Training injury incidence

The training injury incidences in *Papers I and III* agree with those reported in the literature as seen in Table 1. Until now, however, the risk of training injury during international championships has not been known. In all three championships studied in *Paper IV*, the training injury incidence was very low (2.1-2.9 injuries per 1000 training hours). The most plausible explanation is that training at tournaments is mainly devoted to recovery in contrast to more high-intensity exercises during the regular league season. However, the content of training was not studied in detail and this is a limitation when comparing incidences between club football and international tournaments. Training content (strength training, aerobic endurance training, football-specific exercises etc.) should therefore ideally be reported in future studies, since the risk of training injury is certainly higher in match-like football exercises on the pitch than during a recovery session in the pool.

Regional differences

In *Paper III*, the four English and Dutch teams had a higher match injury incidence and also a higher incidence of severe injury compared to the seven Mediterranean clubs. Regional differences in the injury epidemiology have been found in two other recent studies as well.^{68,77} The first study, comparing the Swedish and Danish men's elite leagues, also found a significant difference between the countries in the incidence of severe injury.⁶⁸ However, that study showed a significant difference in training injury incidence, but not for match play. The

second study compared women's football in the most northern and southern parts of Sweden at intermediate level of play.⁷⁷ In this study, the incidences of match injury and moderate injury (absence 8-28 days) were significantly higher among the northern teams. A third study, however, could not show any regional differences between the closely situated Czech Republic and the Alsace region of Germany and France in youth football.⁸² Clearly, further studies are required, but results from senior football suggest that regional differences may influence injury epidemiology. Possible factors which could be involved include playing intensity, playing style, rule interpretation, weather and pitch conditions etc., but none of these factors were evaluated in any of these studies.

Pre-season preparation

The pre-season in Sweden usually starts at the latest in January and lasts until the beginning of April. On the contrary, the pre-season in Western Europe lasts from the beginning of July to the end of August. There is thus a great difference in the time available for physical preparation in Sweden compared to most Western European countries, but the optimal time needed for preparation is not known.

In *Paper I*, both training and overuse injury incidences in the Swedish elite league were higher during the pre-season compared to the competitive season. In contrast, the incidence of overuse injury was not different between the pre-season and the competitive season (3.6 ± 2.7 vs. 2.3 ± 1.4 injuries per 1000 hours, $p=0.25$) in *Paper III* (*unpublished results*). Likewise, no difference in training injury incidence between periods was found in that paper. Since some injury rates were higher during the Swedish pre-season, it could be speculated that the average load, frequency and/or duration of the conditioning may not be optimal. Concern has also recently been expressed over the high number of injuries occurring during the pre-season in English professional football.¹⁴⁵ The pre-season is very important in the preparation of the squad physically prior to the competitive season, and it has been shown in Icelandic elite football that teams with a longer pre-season preparation have fewer injuries during the competitive season than teams with a shorter pre-season.⁹ However, it seems that the optimal content and duration of preparation needs to be addressed further, at least from the injury perspective.

Nature of football injury

In this thesis, 85-88% of all time loss injuries affected the lower extremities (*Papers I, III and IV*) which is consistent with the findings of other studies (77-93%).^{9,10,40-42,62,63,68,70,72,78,106}

Thigh strain

In *Papers I, III and IV*, thigh strain was the most frequent injury comprising 13-16% of all injuries. This finding agrees well with other recent studies reporting frequencies of 10-22%.^{9,10,42,63,68,72,106} The strain mainly affects the hamstrings which in turn have been reported to constitute between 9-16% of all time loss injuries.^{9,10,24,63,72,106,147} Around two-thirds of the thigh strains in *Paper III* affected the hamstrings which is in the lower range of those figures reported previously (67-88%).^{9,10,63,106} The exact relationship between posterior and anterior strains was unclear in *Paper I*, since these details were not originally required on the injury form. Six of ten thigh strains in *Paper IV* affected the hamstrings (*unpublished results*), but the number was too low to allow meaningful statistical analysis.

The incidence of hamstring strain in *Paper III* was 1.0 ± 0.6 injuries per 1000 hours; 4.4 ± 3.5 injuries per 1000 match hours and 0.3 ± 0.2 injuries per 1000 training hours (*unpublished results*). Similarly, the incidence of hamstring strain in Icelandic elite football in two studies was reported to be 0.9-1.5 injuries per 1000 hours; 3.0-4.1 injuries per 1000 match hours and 0.4-0.5 injuries per 1000 training hours.^{9,10} These overall incidences are consistent with the figures recently found in a study on Swedish elite football where the hamstring strain incidence was 1.0 injuries per 1000 hours in male and 0.8 injuries per 1000 hours in female elite footballers.⁷² Even if the game has become faster over recent decades,¹³⁷ it is unknown whether the incidence of hamstring strain is increasing, since there are no historical hamstring strain data for comparison.

Knee sprain

Knee sprains vary in severity from slight capsular sprains without instability to complete ligament ruptures. The ACL rupture is by far the most commonly studied knee injury in sports, but the literature describing its epidemiology is quite scarce. No ACL injury was recorded in *Paper IV*, but in the other papers 0.6% (*Paper I*), 0.9% (*Paper III*) and 1.9% (*Paper V*) of all injuries were ACL injuries as shown in Table 9. In other studies on elite football, the percentages have been 1.2-4.7% of all time loss injuries.^{9,10,40-42}

Table 9. Number (%) of ACL injuries and ACL injury incidences (number of ACL injuries per 1000 hours) as reported in papers I, III and V.

Study	Number (%) of ACL injuries			ACL injury incidence		
	Training	Match	Total	Training	Match	Total
<i>Paper I</i>	2 (0.5%)	3 (1.0%)	5 (0.6%)	0.02	0.26	0.05
<i>Paper III</i>	1 (0.3%)	5 (1.4%)	6 (0.9%)	0.02	0.44	0.09
<i>Paper V</i>						
- Men	2 (0.7%)	6 (2.4%)	8 (1.5%)	0.03	0.66	0.11
- Women	3 (1.7%)	5 (4.0%)	8 (2.7%)	0.06	0.65	0.15

* *Unpublished results*

The ACL injury incidences found in this thesis are also listed in Table 9. Incidences varied between 0.05-0.15 ACL injuries per 1000 hours; 0.26-0.66 ACL injuries per 1000 match hours and 0.02-0.06 ACL injuries per 1000 training hours. The ACL injury incidence in this thesis was thus much higher during match play which has also been described in other similar studies.^{10,42,55} One study on the American professional women's league, found an incidence of 0.09 ACL injuries per 1000 hours; 0.9 ACL injuries per 1000 match hours and 0.04 ACL injuries per 1000 training hours.⁵⁵ Another study on the two highest Icelandic men's leagues, showed an incidence of 0.15 ACL injuries per 1000 hours; 0.5 ACL injuries per 1000 match hours and 0.07 ACL injuries per 1000 training hours.¹⁰ However, a third study, on the German women's elite league found a very high incidence of 2.2 ACL injuries per 1000 match hours and no training-related ACL injury at all.⁴² One possible explanation for the low ACL injury incidences found in the present thesis and most other studies could represent a "pre-selection" phenomenon in which players who are at risk of ACL injury may have had their injury earlier in their career, preventing them from reaching the elite level.⁵⁶

Ankle sprain

The ankle sprain incidence in this thesis was: 0.6 ± 0.5 injuries per 1000 hours (2.0 ± 1.9 injuries per 1000 match hours and 0.4 ± 0.4 injuries per 1000 training hours) in *Paper I*, 1.0 ± 0.5 injuries per 1000 hours (3.0 ± 2.0 injuries per 1000 match hours and 0.6 ± 0.3 injuries per 1000 training hours) in *Paper III*, and 0.6 ± 0.5 injuries per 1000 hours (2.0 ± 1.9 injuries per 1000 match hours and 0.4 ± 0.4 injuries per 1000 training hours) in *Paper IV* (*unpublished results*). The ankle sprain incidence in Icelandic elite football has recently been reported to be 0.6 injuries per 1000 hours; 2.3 injuries per 1000 match hours and 0.2 injuries per 1000 training hours.¹⁰ The overall incidence in another recent study on Swedish elite football was 0.8 injuries per 1000 hours in both male and female football.⁷²

In contrast to hamstring strain, some previous incidence data for ankle sprains in elite football exist. These incidences are higher than those listed above: 1.7-1.8 injuries per 1000 hours in the two highest male divisions in Sweden during the early 1980s,³³ 1.3 injuries per 1000 hours in Icelandic elite football 1991,⁹ and 1.5 injuries per 1000 hours for the Swedish men's national team during the 1990s.³⁶ It seems therefore that the incidence of ankle sprain may have decreased over the last two decades which in turn could be due to an increase in knowledge on how to prevent recurrent ankle sprain.^{32,128,131,136}

Circumstances of football injury

In *Paper IV*, 41% of match injuries resulted from non-contact and these were more common in the second half, which is similar to another study where strains were more common in the second part of a match or training session.⁹ In addition, an increasing number of non-contact injuries towards the end of each half was seen in the World Cup 2002⁸⁴ as well as for hamstring strain in English professional football.¹⁴⁷ All these findings could possibly be associated with fatigue and, interestingly, one study on European professional footballers showed that there was a significant reduction in high-intensity running in the second compared to the first half of a match.¹⁰⁵ In that study, there was also a significantly lower distance covered in high-intensity running during the last 15 minutes of each half, but no study has so far combined proper time-motion analysis with injury data. The tendency to develop fatigue may also be higher in international championships due to the burden of a long preceding league season. It is known that it is difficult to find the optimal balance between rest after the league season and preparation for an international championship,¹⁷ and a congested match calendar at the end of the league season 2001-2002 could have contributed to the high number of exhausted and injured players during the men's World Cup 2002.^{37,84}

Severity of football injury

Knee injury was the most frequent severe injury (31-36%) reported in *Papers I, III and IV* which agrees well with several other studies.^{23,42,68,106,110,116} The frequency of severe injury was highest in the European Championships (20%) and lowest in the Swedish elite league (9%). In all papers, a player was classified injured until clearance from the club medical staff was obtained.⁶⁹ It should, however, be kept in mind that good medical care may actually work in the opposite direction as regards time lost. Since incomplete rehabilitation and premature return to sports is commonly believed to increase the risk of injury,^{9,32,110} it seems logical not to force the comeback to the pitch. However, only a few studies have attempted to introduce guidelines for return to play after injury.^{52,71}

Consequences of football injury

Fortunately, most football injuries are not severe. Some injuries may, however, force a player to give up his or her football career earlier than desired.^{27,34} ACL injury is known to interfere with return to football, at least at the same level as prior to the injury.^{19,40,125,132} This injury is also the most common cause of football-related medical disability.⁴⁶ In the present thesis, the prevalence of previous ACL injury was high in many of the cohorts studied; 8% in the Swedish men's elite league 2001 in *Paper II*, 7% (19/266) in the European professional clubs 2001-2002 in *Paper III* (*unpublished results*), 17% (27/160) in the women's European Championship 2005 in *Paper IV* (*unpublished results*), 5% in the Swedish men's elite league 2005 (*Paper V*) and 15% in the Swedish women's elite league 2005 (*Paper V*). In addition, the prevalence of previous ACL injury has been shown to be 13% in the German women's elite league 2003-2004⁴³ as well as 17% in the Swedish women's elite league 2004.¹⁴² All these figures suggest that the prevalence of previous ACL injury is two to three times higher in female than in male elite players. The results also suggest that many players can "survive" after ACL injury and are able to play football at a high level again.

However, even if a player is able to return to play after an ACL injury, he or she may be more prone to future knee problems. The risk of suffering a new ACL injury (re-rupture or contralateral tear) seems to be increased in female elite footballers.⁴³ The rate of subsequent knee injury of any kind is also high as seen among male elite players in *Paper II*. Interestingly, half of the players who underwent ACL reconstruction during 2000 suffered an overuse injury in the reconstructed knee shortly after their return to football in the subsequent season. Likewise, three of seven reconstructed male players in *Paper V* sustained new knee injuries requiring additional surgery within a few months after their comebacks to the pitch. These results suggest that the first months after return are of specific concern and it is therefore worrying that standardised criteria for return to play after ACL injury are lacking.^{92,109} Premature return could therefore be an important factor contributing to the high rate of new injury, but there are several other possible explanations as well. First, the transition from rehabilitation to full participation in team training and match play may result in overload of still not healed or remodelled tissues. Second, even if satisfactory mechanical stability is achieved after ACL reconstruction, the knee may still suffer from altered kinematics²⁰ and diminished proprioception.^{48,120} Third, ACL injury is often combined with concomitant bone bruising and lesions to the menisci or joint cartilage,¹ which could make the joint more vulnerable to loads which were tolerated before the ACL injury. Fourth, it is also possible that some players may be injury-prone due to an aggressive playing style or high risk-taking behaviour etc. There was, however, no evidence in *Paper II* that players with a history of previous ACL injury were more prone to suffer injuries to the lower limbs that were not related to the knee.

Risk factors for football injury

Although an injury may appear to have been caused by a single inciting event, it is most probable that it results from a complex interaction between intrinsic and extrinsic factors at the time of injury.¹⁰² Investigating a single risk factor separately would thus not yield a true picture in most cases. It has therefore been recommended that multivariate analyses should be used instead of univariate analyses when data on multiple risk factors are available.^{15,102} However, most studies in the field have so far used univariate statistics despite access to multiple risk factor data.¹⁵

An example of this methodological bias is seen when reviewing the studies which have analysed gender as a risk factor for ACL injury in football. The risk of ACL injury in post-pubertal adolescents and adults has been found to be higher among female players in several studies.^{2,7-8,19,104,125,129} In American collegiate football, the risk of ACL injury has been reported to be 0.31-0.33 ACL injuries per 1000 athlete-exposures in female players and 0.11-0.13 ACL injuries per 1000 athlete-exposures in male players (relative risk 2.4-2.8).^{2,7,8,104} These college players are typically 17-22 years old, but since no specific age data were reported it is unclear if the age at injury differs between men and women. A higher rate of ACL injury in female football players has also been found in two retrospective studies from Scandinavia. In the first study, based on Swedish insurance data, licensed female players had a 1.9 times higher risk of ACL injury in general and 6.7 times higher risk at the elite level.¹²⁵ Female players younger than 20 years had a double risk compared to their male counterparts. In the second study, females had a 1.8 times higher risk of ACL injury according to a questionnaire survey in Norway.¹⁹ Female players with ACL injury were significantly younger than their male counterparts (19 vs. 27 years). Finally, in one study based on insurance claims from American youth football, ACL injury was most frequently reported in 16 year-old females and the claims were twice as common in female players aged 13-17 years compared to their male counterparts.¹²⁹

Age thus seems to be a confounding factor when comparing the risk of ACL injury in men's and women's football. Since age at injury is lower in women, it is highly probable that the differences observed in most studies would be lower if the ratios had been standardised for age. As shown in *Paper V*, age was associated with ACL injury incidence in women, the risk decreasing by 24% per year increase in age, but no such association was seen in men. Interestingly, younger female players (up to 19 years) in this cohort had the lowest injury rate of all players and also the lowest rate of severe injury.⁷² Although anatomical, neuromuscular and hormonal factors have repeatedly been proposed to be responsible for this gender-related bias, there is no convincing scientific evidence in the literature.^{57,66,108} In one study on different levels of play in women, it was hypothesised that younger players had a lower physical capacity.¹⁵⁰ In that study, players older than 20 years were significantly stronger in knee flexion, but although the hamstrings are agonists to the ACL, the differences were small and the clinical relevance was questioned. No difference was seen in functional performance (hop tests) or aerobic capacity between the two age groups and the prevalence of generalised joint laxity was also equally common. Generalised joint laxity has otherwise been shown to be a significant risk factor for injury in female footballers,^{134,151} but this has not been studied at the elite level, and not for ACL injuries in particular.

When studying age, gender or other risk factors that can be assumed to represent a characteristic of a person, it is recommended that the person is used as the unit of analysis.¹⁵ Using the limb as the unit of analysis could, however, be an alternative if a risk factor can be assumed to be a characteristic of the limb more than the person.¹⁵ Local scar tissue and unilateral deficits in ROM could, for instance, be argued to primarily be a characteristic of the limb. However, the decision to use the person or the limb as the unit of analysis can be difficult sometimes as exemplified by the ACL injury. It has been reported that some individuals are genetically predisposed to ACL injury^{45,58} and even after unilateral ACL injury, bilateral deficits in proprioception are common.¹²⁰ It therefore seems that some factors associated with ACL injury are more related to the person than the injured limb. This notion is further supported in a recent study where the risk of new ACL injury after previous ACL injury was increased when using the player, but not the knee, as the unit of analysis.⁴³ However, the risk of new knee injury after previous ACL injury in *Paper II* was significantly

increased regardless of whether the player or the knee was used as the unit of analysis. The most plausible explanation for this discrepancy between the studies is that all knee injuries were studied in *Paper II*, but only ACL injuries in the former study.⁴³ Another important difference is that only male players were investigated in *Paper II* whereas the German study was conducted on female players.

Prevention of football injury

No intrinsic risk factor has been able to explain injury occurrence in general except for previous injury. It has therefore been suggested that studies aimed at preventing injury should focus more on the teams and their environment and not on the individual player.⁷⁶ It seems, for instance, important to encourage fair play, since as many as 26% of all traumatic match injuries in *Paper I* (*unpublished results*), 28% in *Paper III* (*unpublished results*) and 30% in *Paper IV* were due to foul play. Another interesting finding from the injury prevention perspective is that players seldom use shin-guards during training and almost never perform cool-down exercises after training and match play as seen in English professional football.⁶⁰

Studies should also focus more on common injuries such as hamstring strains to be able to reduce the number of injuries substantially. It seems, for instance, that the preventive research on ankle sprains^{32,128,131,136} has successfully reduced these injuries in football.^{9,10,33,36,72} Since severe injuries have a great impact on the time a player is out,²⁸ it is important to study these injuries. Most of these injuries are, however, uncommon and it is well-known that either very large samples or long observation periods are required when studying severe injuries such as ACL rupture.¹⁵ Nevertheless, a few studies have shown promising results in preventing ACL injuries in football.^{22,100} The former study evaluated balance board training in male amateur players,²² but is unfortunately associated with severe methodological limitations making the results seriously questionable. The latter study is of higher methodological quality and showed a 74-88% reduction in the frequency of ACL injury among female players 14-18 years old after introduction of a multi-modal programme consisting of warm-up, stretching, strengthening, plyometrics and agilities.¹⁰⁰

That ACL injuries can be prevented in adolescent female players is important, since the risk of ACL injury seems to be highest in the teenage as both shown in *Paper V* and in several other previous studies.^{2,7,8,19,104,125,129,142} Even if women's football is growing fast, it is probably still quite common that talented teenagers participate more or less regularly in senior football. One Swedish study based on insurance claims data showed, for instance, that as many as 39% of the ACL injuries among female players younger than 16 years occurred while playing in senior teams.¹³⁵ The conclusion of that study was that females younger than 16 years should not be allowed to participate in senior matches. Similarly, a minimum age of 20 years for playing in the women's elite league in Sweden has also been suggested with respect to the high risk of ACL injury.¹²³

CONCLUSIONS

- Injury during match play was higher than during training (*Papers I, III and IV*)
- Thigh strain (hamstring strain) was the single most common injury (*Papers I, III and IV*)
- There was no difference in apparent injury incidence between the time loss and tissue injury definitions (*Paper I*)
- The pre-season was associated with a higher incidence of training injury, overuse injury and re-injury (*Paper I*)
- Different geographic regions in Europe showed different injury epidemiology (*Paper III*)
- Players with international duty were exposed to more matches during the season, but did not have a higher injury incidence (*Paper III*)
- There was no difference in injury incidence between the men's, the women's and the men's U-19 European Championships (*Paper IV*)
- Teams eliminated after the group stage in the women's European Championship had a higher match injury incidence than the teams that went on to the final stage (*Paper IV*)
- Non-contact match injuries were common, especially in the second half (*Paper IV*)
- The prevalence of previous ACL injury was higher in female than in male elite players (*Papers II, III, IV and V*)
- Previous ACL injury was associated with a higher incidence of new knee injury (*Paper II*)
- There was no gender-related difference in ACL injury incidence (*Paper V*)
- Increase in age was associated with a decrease in ACL injury incidence among female elite players (*Paper V*)

SUMMARY

The purpose of this thesis was to study the injury characteristics in elite football, and risk factors for injury with special emphasis on anterior cruciate ligament injury. All five papers followed a prospective design using a standardised methodology. Individual training and match exposure was recorded for all players participating as well as all injuries resulting in time loss. Severe injury was defined as absence from play longer than 4 weeks.

In *Paper I*, all 14 teams in the Swedish men's elite league were studied during the 2001 season. In this paper, all tissue damage regardless of subsequent time loss was also recorded. There were no differences in injury incidence between the two injury definitions during match play (27.2 vs. 25.9 injuries per 1000 hours, $p=0.66$) or training (5.7 vs. 5.2 injuries per 1000 hours, $p=0.65$). Significantly higher injury incidences for training injury, overuse injury and re-injury were found during the pre-season compared to the competitive season. Thigh strain was the single most common injury (14%).

In *Paper II*, 8% of all players in the Swedish men's elite league 2001 had a history of previous ACL injury at the start of the study period. These players had a higher incidence of new knee injury during the season than players without previous ACL injury (4.2 vs. 1.0 injuries per 1000 hours, $p=0.02$). The higher incidence of new knee injury was seen both when using the player (relative risk 3.4, 95% CI 1.8-6.3) and the knee (relative risk 4.5, 95% CI 2.3-8.8) as the unit of analysis.

In *Paper III*, eleven clubs in the men's elite leagues of five European countries were studied during the 2001-2002 season. The incidence of match injury was higher for the English and Dutch teams compared to the Mediterranean teams (41.8 vs. 24.0 injuries per 1000 hours, $p=0.008$) as well as the incidence of severe injury (2.0 vs. 1.1 injuries per 1000 hours, $p=0.04$). Players having international duty had a higher match exposure (42 vs. 28 matches, $p<0.001$), but a tendency to a lower training injury incidence (4.1 vs. 6.2 injuries per 1000 hours, $p=0.051$). Thigh strain was the most common injury (16%) with posterior strains being more frequent than anterior ones (67 vs. 36, $p<0.0001$).

In *Paper IV*, the national teams of all 32 countries that qualified for the men's European Championship 2004, the women's European Championship 2005 and the men's Under-19 European Championship 2005 were studied during the tournaments. There were no differences in match and training injury incidences between the championships. Teams eliminated after the group stage in the women's championship had a significantly higher match injury incidence compared to teams going to the semi-finals (65.4 vs. 5.0 injuries per 1000 hours, $p=0.02$). Non-contact mechanisms were ascribed for 41% of the match injuries and these injuries were more common in the second half.

In *Paper V*, all 12 clubs in the Swedish women's elite league and 11 of 14 clubs in the men's elite league were studied during the 2005 season. The prevalence of a history of previous ACL injury at the start of the study was three times higher among the female players (15% vs. 5%, $p=0.0002$). During the season, 16 new ACL injuries were recorded. There was a tendency to a lower mean age at injury among the women (20 vs. 24 years, $p=0.069$). Adjusted for age, no gender-related difference in the incidence of ACL injury was seen (relative risk 0.99, 95% CI 0.37-2.6). Age was associated with ACL injury incidence in women where the risk decreased by 24% for each year increase in age (relative risk 0.76, 95% CI 0.59-0.96).

SUMMARY IN SWEDISH – SVENSK SAMMANFATTNING

Syftet med avhandlingen var att undersöka skaderisk och skademönster i elitfotboll samt att studera riskfaktorer för skada huvudsakligen inriktat på främre korsbandsskada. Samma metod användes genomgående i de fem delarbetena som alla var prospektiva. Individuell exponering under träning och match registrerades för samtliga spelare liksom alla skador som ledde till frånvaro från fotboll. Svåra skador definierades som frånvaro mer än 4 veckor.

I *delarbete I* studerades alla 14 klubbar i Allsvenskan under säsongen 2001. I detta arbete registrerades också alla vävnadsskador även om de inte ledde till någon frånvaro. Det var ingen skillnad i skadefrekvens mellan de två sätten att definiera skada vare sig under match (27,2 jämfört med 25,9 skador per 1000 timmar, $p=0,66$) eller träning (5,7 jämfört med 5,2 skador per 1000 timmar, $p=0,65$). Skaderisken för träningsskador, överbelastningsskador och återfallsskador var högre under försäsongen jämfört med tävlingssäsongen. Lårmuskelbristning var den enskilt vanligaste skadan (14%).

I *delarbete II* hade 8% av alla spelare i Allsvenskan 2001 en anamnes på tidigare främre korsbandsskada vid studiestart. Dessa spelare hade en högre frekvens av nya knäskador under säsongen än spelare utan tidigare främre korsbandsskada (4,2 jämfört med 1,0 skador per 1000 timmar, $p=0,02$). Denna högre skaderisk sågs både när spelaren (relativ risk 3,4, 95% KI 1,8-6,3) och knäleden (relativ risk 4,5, 95% KI 2,3-8,8) användes som enhet för analysen.

I *delarbete III* studerades elva toppklubbar i fem europeiska länder under säsongen 2001-2002. Skadefrekvensen under match var högre hos de engelska och holländska klubbarna än i klubbarna från Medelhavsområdet (41,8 jämfört med 24,0 skador per 1000 timmar, $p=0,008$) liksom frekvensen av svåra skador (2,0 jämfört med 1,1 skador per 1000 timmar, $p=0,04$). Spelare med landslagsuppdrag hade en högre matchexponering (42 jämfört med 28 matcher, $p<0,001$), men en tendens till en lägre skadefrekvens under träning (4,1 jämfört med 6,2 skador per 1000 timmar, $p=0,051$). Lårmuskelbristning var den enskilt vanligaste skadan (16%) och bristningar i hamstrings var vanligare än i quadriceps (67 vs. 36 skador, $p<0,0001$).

I *delarbete IV* studerades de 32 landslag som kvalificerade sig till Europamästerskapen i fotboll för herrar 2004, damer 2005 och herrjuniorer (U-19) 2005. Ingen skillnad i skadefrekvens kunde påvisas mellan de olika turneringarna. De lag som slogs ut i gruppspellet i dam-EM hade emellertid en högre skadefrekvens under matchspel än de lag som kvalificerade sig för finalrundan (65,4 jämfört med 5,0 skador per 1000 timmar, $p=0,02$). Av alla matchskador i de tre turneringarna uppstod 41% utan någon kontaktsituation och dessa skador var vanligare i andra halvlek.

I *delarbete V* studerades samtliga 12 klubbar i Damallsvenskan och 11 av 14 klubbar i Allsvenskan under säsongen 2005. Förekomsten av tidigare främre korsbandsskada vid studiestart var högre hos de kvinnliga elitspelarna (15% jämfört med 5%, $p=0,0002$). Under säsongen inträffade 16 nya främre korsbandsskador. Det fanns en tendens till lägre ålder vid skadetillfället hos kvinnorna (20 jämfört med 24 år, $p=0,069$). Efter korrigering för skillnaden i ålder kunde ingen könsskillnad i risken för främre korsbandsskada påvisas (relativ risk 0,99, 95% KI 0,37-2,6). Risken för främre korsbandsskada sjönk med 24% per år med ökad ålder hos de kvinnliga spelarna (relativ risk 0,76, 95% CI 0,59-0,96).

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BASELINE FORM

CLUB:

By signing this form, I hereby certify that I have been informed about the UEFA research project by my team physician: and that I am willing to participate in the study

Name	Code	Age (years)	Height (cm)	Weight (kg)	Dominant leg	Previous major surgeries and injuries (absence > 1 month)	Player signature
	01						
	02						
	03						
	04						
	05						
	06						
	07						
	08						
	09						
	10						
	11						
	12						
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	20						
	21						
	22						
	23						
	24						
	25						

EXPOSURE FORM

CLUB: **MONTH:**

X = participation in training session (min)

A = participation in first team match (min)

B = participation in reserve team match (min)

N = participation in national team (min)

AT = absence from training because of injury

AM = absence from match because of injury

0 = absence due to other reason

Contact person:

Fax: **Tel:**

Mobile: **E-mail:**

[illegible]

INJURY FORM

Name: **Team:**

Date of injury: **Code:**

Activity: ☐ Training session ☐ Match

Injury type: ☐ Sprain ☐ Joint injury ☐ Strain

☐ Contusion ☐ Fracture ☐ Dislocation

☐ Other traumatic injury ☐ Overuse injury

Injury location: ☐ Foot ☐ Ankle ☐ Lower leg

☐ Knee ☐ Thigh ☐ Hip/groin

☐ Back ☐ Head/face/neck ☐ Other location

Injury side: ☐ Right ☐ Left ☐ Bilateral

Re-injury: ☐ No ☐ Yes

Violation of rules: ☐ No ☐ Yes, opponent ☐ Yes, own

Injury severity: ☐ Slight ☐ Minor

☐ Moderate ☐ Major

Diagnosis:

Comments: