KNEE LIGAMENT INJURIES IN MALE PROFESSIONAL FOOTBALL PLAYERS

MATILDA LUNDBLAD

Department of Orthopaedics
Institute of Clinical Sciences at Sahlgrenska Academy
University of Gothenburg
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UNIVERSITY OF GOTHENBURG

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matildalundblad@gmail.com

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Correspondence: matildalundblad@gmail.com

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Knee ligament injuries are common in professional football and entail a significant time loss from football, but studies of knee ligament injuries other than anterior cruciate ligament (ACL) injuries are scarce.

The aim of this thesis was prospectively to study the epidemiology and characteristics of medial collateral ligament (MCL), lateral collateral ligament (LCL) and posterior cruciate ligament (PCL) injuries in male professional football players with the main emphasis on MCL injuries. A further aim was to analyse whether professional football players are more susceptible to ACL injury after returning to play from any previous injury.

The main sample in this thesis is from the UEFA Elite Club Injury Study (Studies I-IV) that has been ongoing since 2001. In addition, data from the English Premier League (Studies II-IV) and the Nordic Football Injury Audit (Study III) were used during 2011 and 2014 and 2010 and 2011 respectively. All four studies followed a prospective design using standardised methodology, which documents training and match exposure and time loss injuries on an individual basis. Injury severity was evaluated according to length of time loss. Injury rate and the rate ratio (RR) for injury between training and matches were calculated. In Study II, further details on clinical grading, imaging findings and specific treatments were collected between 2013 and 2016 for all injuries, with MCL injury as the main diagnosis. In Study III, first-time complete ACL injuries were matched 1:1 according to team, age and playing position with control players who did not have a current injury and the 90-day period prior to the ACL injury was analysed for injuries and compared by using the odds ratio (OR) and a 95% confidence interval (CI).

The match injury rates were significantly higher than the training injury rates for MCL injury (1.31 vs 0.14/1,000 h, RR 9.3, 95% CI 7.5 to 11.6, p<0.001), LCL injury (0.21 vs 0.02/1,000 h, RR 10.5, 95% CI 7.3 to 15.1 p<0.001) and PCL injury (0.056 vs 0.003/1,000 h, RR 20.1, 95% CI 8.2 to 49.6, p<0.001). There was a significant average annual decrease for MCL injuries of 6.9% (p=0.023) between 2001 and 2012 in Study I and for LCL injuries of 3.5% (p=0.006) between 2001 and 2018 in Study IV respectively. For MCL and LCL injuries, the majority were mild to moderate injuries, i.e. the lay-off time was less than four weeks (71.7%, and 72.7%, respectively). On the other hand, most PCL injuries (57.1%) were severe injuries causing more than four weeks' lay-off. In total, 75% (98/130) of all MCL injuries in Study II and 58% (63/108) of all LCL injuries and 54% (14/26) of all PCL injuries in Study IV were related to contact injury mechanisms. For MCL injuries, the agreement between clinical examination and magnetic resonance imaging (MRI) for grading was 92% in Study II. Using a brace in the treatment of grade II MCL injuries was associated with a longer lay-off compared with not using a brace (41.5 (SD 13.2) vs. 31.5 (SD 20.3) days, p = 0.010) in Study II. The odds of a player with an ACL injury sustaining an injury in the previous 90-day period did not differ significantly from that of controls (OR 1.20, 95% CI, 0.66-2.17, p = 0.65).

A men's professional team, typically with 25 players in the squad, can expect approximately two MCL injuries a season and one LCL injury every third season, while a PCL injury can only be expected every 17th season. These knee ligament injuries typically occur during matches and are associated with a contact injury mechanism. Moreover, the collateral ligament injury rates have decreased significantly since 2001. For players sustaining a grade II MCL injury, using a stabilising knee brace was associated with a longer lay-off period compared with players who did not use a brace, indicating that routine bracing may not be an optimal therapeutic option and is better determined individually.

SAMMANFATTNING

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Ligamentskador i knät är vanligt förekommande inom professionell fotboll och medför en betydande frånvaro från fotboll, men det finns inte många studier på andra knäligamentskador än främre korsbandsskador.

Målet med den här avhandlingen är att prospektivt studera epidemiologin och skadans karaktär för inre sidoledbandet, yttre sidoledbandet och bakre korsbandet inom professionell herrfotboll med huvudsaklig inriktning på inre sidoledbandet. Ytterligare ett mål var att analysera huruvida professionella fotbollsspelare har en ökad risk för främre korsbandsskador efter att de återgått till spel från en tidigare skada.

Merparten av materialet i den här avhandlingen kommer från UEFA Elite Club Injury Study (Studier I-IV) som sedan 2001 har innefattat 68 professionella herrfotbollslag. Andra kohorter som bidragit med data är English Premier League (Studie II-IV) och Nordic Football Injury Audit (Studie III) där data samlades in mellan 2011 och 2014, samt 2010 och 2011. Alla fyra studier följde en prospektiv design och använde standardiserad metodologi. Tränings- och matchexponering, samt skador som lett till frånvaro från fotboll registrerades på individuell basis. Detaljer kring klinisk gradering, röntgenologiska fynd och specifik behandling registrerades från 2013 till 2016 för alla skador med inre sidoledbandet som huvuddiagnos (Studie II). Förstagångsskada på främre korsbandet registrerades och matchades för lag, ålder och spelarposition med kontrollspelare som ej var skadade (1:1) och 90-dagarsperioden före främre korsbandsskadan analyserades för skador och jämfördes med kontrollerna med odds ratios (ORs) och 95% CIs.

Det är en signifikant ökad risk att få en inre sidoledbandsskada på match jämfört med träning (1,31 vs 0,14/1000 h, rate ratio [RR] 9,3, 95% CI 7,5 to 11,6, p<0,001), en yttre sidoledbandsskada (0,21 vs 0,02/1000 h, RR 10,5, 95% CI 7,3 to 15,1 p<0,001) och en bakre korsbandsskada (0,056 vs 0,003/1000 h, RR 20,1, 95% CI 8,2 to 49,6, p<0,001). Mellan åren 2001 och 2012, samt 2001 och 2018, minskade inre sidoledbandsskador och yttre sidoledbandsskador betydligt, med 6,9% (p=0,023) från 2001 och 2012 i Studie I, respektive 3,5% (p=0,006) från 2001 och 2018 i Studie IV. Majoriteten av inre och yttre sidoledbandsskador är lindriga till medelsvåra, med andra ord har de en frånvaro från fotboll som är kortare än fyra veckor (71,7% respektive 72,7%). Å andra sidan så är de flesta bakre korsbandsskador (57,1%) svåra skador som leder till mer än fyra veckors frånvaro från fotboll. Totalt 75% (98/130) av alla skador på inre sidoledbandet i studie II, 58% (63/108) av alla skador på yttre sidoledbandet och 54% (14/26) av alla bakre korsbandsskador i studie IV var relaterade till kontaktmekanism.

För inre sidoledbandsskador visade klinisk undersökning och magnetkameraundersökning nästintill full överensstämmelse (92% överensstämmelse). Användandet av ortos ökade frånvarotiden från fotboll för grad II-skador på inre sidoledbandet jämfört med spelare utan ortos med 41,5 (SD 13,2) jämfört med 31,5 (SD 20,3) dagar, p = 0,010). Oddsen att en spelare med främre korsbandsskada ådrar sig en skada under 90-dagarsperioden före skadan skiljde sig inte från kontrollerna (OR 1,20; 95% CI, 0,66-2,17; p = 0,65).

Inom professionell herrfotboll med en typisk spelartrupp på 25 spelare kan ett lag förvänta sig ungefär två inre sidoledbandsskador per säsong, en yttre sidoledbandsskada var tredje säsong och en bakre korsbandsskada var 17:e säsong. Dessa skador uppstår typiskt under match och är relaterade till kontaktmekanism. Vidare har kollateralligamentskadorna minskat signifikant sedan 2001. Spelare som ådragit sig en grad II-skada på inre sidoledbandet och använde en ortos hade en längre återgångstid till fotboll jämfört med spelare som inte använde ortos, vilket indikerar att ortos sannolikt inte ska användas rutinmässigt på grad II-skador för inre sidoledbandet utan att det ska ske en individuell bedömning som stöd för beslut.

LIST OF PAPERS

LIST OF PAPERS

This thesis is based on four studies, referred to in the text by their Roman numerals.

I. The UEFA injury study: 11-year data concerning 346 MCL injuries and time to return to play.
Lundblad M, Waldén M, Magnusson H, Karlsson J, Ekstrand J.
British Journal of Sports Medicine. 2013 47(12):759-62.

II. Medial collateral ligament injuries of the knee in men's professional football players: a prospective three-season study of 130 cases from the UEFA Elite Club Injury Study.
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Knee Surgery Sports Traumatology Arthroscopy. 2019 doi: 10.1007/s00167-019-05491-6.

III. No association between return to play after injury and increased rate of anterior cruciate ligament injury in men's professional soccer.
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Manuscript.

OTHER PUBLICATIONS BY THE AUTHOR NOT INCLUDED IN THE THESIS

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V. ACTN3's R557X single nucleotide polymorphism allele distribution differs significantly in professional football players according to position on the field.
Clos E, Pruna R, Lundblad M, Artells R.
Submitted to Journal of Science and Medicine in Sport.

VI. ACTN3 single nucleotide polymorphism is associated with non-contact musculoskeletal soft-tissue injury incidence in elite professional football players.
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X. Return to play after complex knee injuries: Return to play after medial collateral ligament injuries.
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Return to Play in Football: An Evidence-based Approach. Editors: Musahl, V, Karlsson, J, Krutsch, W, Mandelbaum, B.R, Espregueira-Mendes, J. d'Hooghe, P. Springer Berlin Heidelberg. 2018. Pp 509-524. ISBN 978-3-662-55712-9.

XI. Return to play: Team doctors roles and ethics.
Pruna R, Bahdur K, Lundblad M.
Return to Play in Football: An Evidence-based Approach. Editors: Musahl, V, Karlsson, J, Krutsch, W, Mandelbaum, B.R, Espregueira-Mendes, J. d'Hooghe, P. Springer Berlin Heidelberg. 2018. Pp 811-818. ISBN 978-3-662-55712-9.

XII. The female player: Special considerations.
Wálden M, Gajhede Knudsen M, Lundblad M, Ekstrand J, Hägglund M.
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XIII. Evaluating the muscle injury situation (epidemiology).
Waldén M, Meyer T, Lundblad M, Hägglund M.
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ABBREVIATIONS

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ACL	Anterior cruciate ligament
CI	Confidence interval
CL	Champions League
ECIS	Elite Club Injury Study
EL	Europa League
EPL	English Premier League
FA	Football Association
FIFA	International Federation of Association Football
FRG	Football Research Group
GPS	Global positioning system
HIR	High-intensity running
IQR	Interquartile range
IR	Injury rate
LCL	Lateral collateral ligament
MCL	Medical collateral ligament
NFIA	Nordic football injury audit
OR	Odds ratio
OSTRC	Oslo Sports Trauma Research Center
PCL	Posterior cruciate ligament
RR	Rate ratio
RTP	Return to play
RTS	Return to sports
SD	Standard deviation
UEFA	Union of European Football Associations

1 INTRODUCTION

INTRODUCTION

THE GAME OF FOOTBALL

Few things unite and engage people all over the world as much as football and many would argue that football is more than a game. In fact, the dedication and feelings associated with football resemble a form of worldwide "religion" for some individuals, giving a sense of belonging beyond factors such as geographical background, ethnicity and socio-economy. Football is regarded as the largest sport in the world and the impact of the game has increased steadily during the last 100 years or more. For example, 1.7 billion people watch the men's Champions League final every year. Who would have thought that a game that started out as a military exercise during the Han Dynasty would expand to become a worldwide subject of interest over 2,000 years later?

From an ancient game to modern football

The earliest evidence of humans playing a football-like game originates from the ancient Han Dynasty in China and dates back to 200-300 years BC. The game was called Cuju, or Ts'u-Chü, and was a kind of competitive football game, which was also played in Japan, Korea and Vietnam. Cuju was the earliest form of football and was played by kicking a leather ball filled with feathers and hair. The goal was constructed by fixing a net onto bamboo canes, creating a small opening of only 30-40 cm in width where the ball was supposed to enter for scoring. Already in this ancient form of the game, the use of the hands was not permitted[60].

FIGURE 1. Development from ancient to modern football

Although football was played in various forms and settings during a period of many hundreds of years, it was not until 1863 that modern football started to take shape. This landmark year represents the start of the first governing body in football with the establishment of the Football Association (FA) in England. The initiation of the FA was a result of separating rugby football from association football, which had followed the same course until then. An additional 40 years passed before the International Federation of Association Football (FIFA) was founded in 1904, followed by the Union of European Football Associations (UEFA) in 1954.

Modern football is strictly regulated by FIFA's "Laws of the game"[98]. Originally, the laws of the game were divided into 14 basic rules and today the regulations are divided into 17 basic rules. The "Laws of the game" regulate, for example, the numbers of players in each team (n=11), the playing surface (e.g. natural or artificial turf) and the length of an official game (two halves of 45 minutes and a 15-minute break)[98].

As the game of football evolved and increased in popularity, a gradual transformation took place from players being amateurs to players being employed as football players. In male elite football today, players are by definition professional, meaning that, in contrast to amateur players, they have a signed contract with the club and are paid more for their football activity than the expenses they effectively incur[61].

The impact of football

The joy of the game unites humans across the globe and bridges socio-economic gaps. To play football, you do not need to speak the same language, but you need to understand the game. There are 265 million licensed players worldwide, of which 90% are males and 10% females[61]. In addition, there are all those unlicensed players in every corner of the world, perhaps playing football in the street or at school with the dream of one day entering the same fields as their professional role models. Although there are many players, there are many more spectators. The sport attracts spectators and engages fans on a large scale. Because of the tremendous interest shown by spectators, there is an enormous market for commensurate rights fees for television media, as well as a huge market for sponsorships and merchandise.

UEFA Champions League

The UEFA Champions League (CL) has been an annual tournament since 1992, when the UCL replaced the European Champions Clubs Cup (European Cup), which had been the tournament since 1955. In contrast to the European Cup, which had a straight knockout game schedule, the UCL added an initial group stage before the knockout games. To participate in the UCL, some teams need to play qualifying rounds, while the top teams from some European national leagues qualify directly. The three knockout qualifying rounds start in July and are followed by a play-off round. The remaining 32 clubs at the group stage are divided into eight groups with four teams in each. The top two teams in each group enter the knockout phase, where the two remaining teams play the final in May, which is typically the time at which the competitive season ends in most European countries.

Physical demands in modern football

Performance in football requires that the players adapt both physically and mentally to a variety of complex demands. Football requires the ability to make quick decisions and certain playing skills are needed. Moreover, it requires both high aerobic and anaerobic capacity, good agility, adequate joint flexibility and the appropriate muscular development[89]. The broad areas of requirement mean that a player does not need an extraordinary capacity within any of these performance areas but should possess a reasonable level within all areas. This might be one of the reasons why football is the most popular sport in the world.

The physical capacity of players affects both their technical and tactical performance, as well as their injury frequency[94]. The most commonly used methods for analysing the physical demands of a game at elite level are the Global Positioning System (GPS) or multi-camera systems approach, with predefined five-minute periods[14]. Professional football is a high-intensity, intermittent sport and there has been an increase in high-frequency running over time[26], which results in a larger variation in pace in the current game. A study from the English Premier League showed that the distance covered by the players and the periods of high-intensity running increased by ~30% and ~50% from the 2006/2007 season to the 2012/2013 season respectively. Moreover, the sprint distance and number of sprints increased by ~35 and ~85% respectively[12, 26]. One explanation could be that the tactics of the game have changed over time, meaning that, in modern football, all the player positions are more and more involved in the offensive part of the game. It is important to understand the physical loads in football to be able to implement preventive methods for avoiding injuries. As the physical demands in professional football have increased over time, there is a greater need to study time trends in injuries to determine how the demands have affected the injury risk.

FIGURE 2. Football player training with a GPS.

The intermittent pace of football

Male elite football players cover an average total distance of nine to 14 km during a match[11, 14, 79]. The overall distance covered in a game varies depending on player positions, where midfielders usually cover the greatest distance and central defenders the smallest[105]. Sprinting for men is defined as an activity above ~25 $km \cdot h^{-1}$[15, 16, 19, 20, 27, 79, 88] and constitutes a minority of the activities during a game. Approximately 85% of the game time in football consists of low-intensity activities, like jogging, walking or even standing still[11]. The remaining 15% of high-intensity activity could, however, be regarded as highly demanding activity requiring maximum physical performance. During a game, approximately 1,500-3,000 m is completed in high-intensity running (HIR), ~300-1,100 m in high-speed running and 153-360 m in sprinting[15, 59]. Even though the absolute distance of sprinting is short in a game, these intermittent periods of maximum effort impose heavy demands on a player both physiologically and on the musculoskeletal structures. For example, intense acceleration (>3m/s²) and deceleration (<-3 $m \cdot s^{-2}$) during football games at professional level have been reported to be ~180 and ~188 m respectively[84] and it has been shown in elite football that over half of the non-contact ACL injuries occurred while decelerating[1, 23]. One study has described these intense periods in detail in the English Premier League, by analysing the greatest high-speed running (>19.8 $km \cdot h^{-1}$) distance during a five-minute period. The number of bouts increased by 125% in peak five-minute periods compared with average, while the work:rest ratio increased from an average of 1:12 to 1:2 in peak five-minute periods[26].

EPIDEMIOLOGICAL RESEARCH IN FOOTBALL

The primary goal of epidemiological injury research in sports is to increase our knowledge of injury occurrence in order to target preventive strategies aiming for a reduction in injury rates. Injury surveillance provides knowledge on how frequent injuries are, how injuries occur and what the risk factors are, as well as enabling the evaluation of different treatment strategies and assessments of the prognosis. Several research projects have been initiated for injury surveillance in football by the Oslo Sports Trauma Research Center (OSTRC)[3-5, 8, 9] and, the FIFA Medical Assessment and Research Centre (F-MARC)[30, 63, 86] and the FA Medical Research Programme[28, 52, 53, 115-117].

For the systematic and standardised collection of epidemiological data, the use of common definitions and methods for data collection is important. This will invariably increase the quality of the data, enable comparisons across different settings and act as a foundation for international collaboration studies on injury prevention. A common injury reporting system is necessary for a systematic approach to sports injury surveillance, which was described more than 25 years ago, in 1992, by van Mechelen et al.[102]. The concept describes the importance of first performing an epidemiological evaluation of injuries in order subsequently to introduce prevention strategies[102]. The model described by van Mechelen et al.[102] is based on four steps. The first step is to use epidemiological methodology to establish the extent of the injury. This includes, for example, the incidence and severity of injuries. The injuries are recorded, together with information such as player demographics, exposure time, circumstances when the injury occurred and measurements of injury severity[56]. Step two includes determining the aetiology and mechanisms of the injury. Only then can specific prevention strategies be directed to counter the injury, which is the third step of the model. The implemented prevention strategies should be evaluated to determine the effectiveness of the strategies, which is described as step four and indicates that step one must be repeated. After step four is completed, prevention strategies can also be evaluated in a randomised, controlled trial in order to conduct a study of the highest level of evidence.

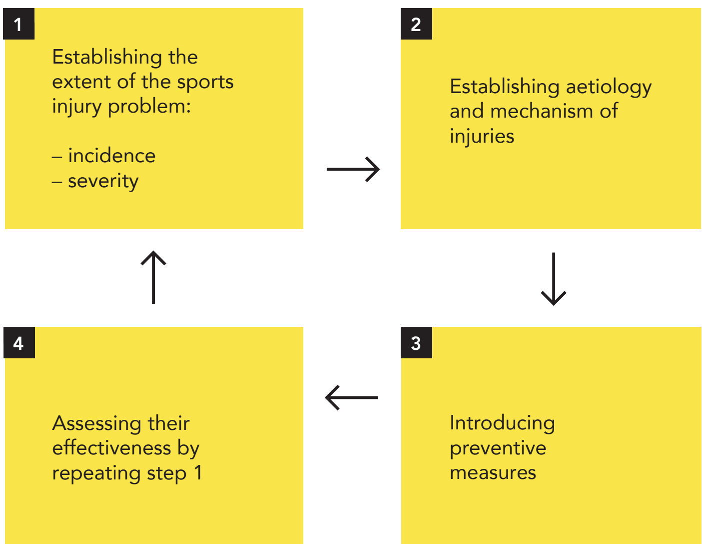

FIGURE 3. Sequence of prevention described by van Mechelen et al[102].

Injuries in professional football

Football is not only the exciting big games and the joy of amateur and youth football. There is a reverse side – the injuries that leave the injured player off the pitch and can pose a risk of persistent impairment or even be career ending. A professional football player has about a 1,000 times higher injury risk compared with a high-risk industrial worker[53]. At professional level, keeping the players healthy and free from injuries can be the difference between failure and success. Injuries have a significant negative effect on team performance and teams that can avoid injuries have greater success based on their final positioning in the league system[9, 32, 58]. Ekstrand et al.[36] showed that match unavailability due to injury is 14% and was constant over 11 consecutive seasons between 2001 and 2012. On average, a professional football player has been shown to sustain two injuries a season, resulting in approximately 50 injuries per team and season[35]. The overall match injury rate is almost seven times higher than the overall training injury rate and this has been reported to be constant over time in professional football teams[36]. The same study reported that severe injuries (defined as causing a lay-off time of more than 28 days) accounted for 17% of all injuries; suggesting that an average team at this playing level can expect approximately eight severe injuries a season. Interestingly, the frequency of severe injuries has been constant since 2000 and onwards[36].

The majority of injuries in professional football are lower-limb injuries[38] and the single most common injury representing 12% of all injuries was a hamstring muscle injury[34], followed by adductor-related injury constituting 9% of all injuries[114]. However, the rate of muscle injuries has not decreased in professional football, despite the preventive measures taken by clubs[36]. Ekstrand et al. reported that hamstring injury rates have instead increased by 4% annually over 13 seasons in men's professional football since 2001[39]. The persistent high frequency of hamstring injuries, together with the high risk of re-injury[101], indicates that hamstring injuries are consistently a major problem in male professional football.

Knee ligament injuries in football

For knee ligament injuries, an overall decrease of 31% was observed between 2001 and 2012[36], with the exception of ACL injuries, where Waldén et al.[113] reported that there was no significant change in injury rate over 15 seasons. Few studies have reported the injury rate and time trends specifically for the other knee ligaments. There is therefore limited information on injury incidence and time trends for medial collateral ligament (MCL), lateral collateral ligament (LCL) and posterior cruciate ligament (PCL) injuries in men's professional football. Perhaps the most noteworthy decrease in injury rate among professional footballers has been observed for ankle sprain injuries. Ankle sprain injuries used to be among the most common injuries in football during the 1980s and 90s, with an incidence of 1.8/1,000 h and 1.3/1,000 h respectively[33]. Although ankle sprains are still one of the most common injuries, there has been a significant decrease in injury rate and a rate of 0.7/1,000 h was reported by Waldén et al. in 2013[36]. This indicates that the efforts made to introduce strategies for preventing ankle sprains have most probably had a successful effect in clubs and in football in general[78, 97].

An MCL injury is one of the most common injuries sustained during sports both in the young population[91] and in elite sports[17]. However, there are few epidemiological studies focusing specifically on collateral ligament injuries in male professional football. Waldén et al.[107] reported that an MCL sprain was the most common knee ligament sprain in the Swedish first league of football, constituting 54% of all knee ligament sprains. The ACL is more commonly injured among professional football players in comparison with the PCL[40] and an ACL injury is also more common for the general population, with the research describing the hazards of ACL in terms of surgery and a long rehabilitation before the players can return to play (RTP) – if they can RTP at all.

Among previous studies of knee ligament injuries, some studies have had knee ligament injury as the main outcome. However, the majority of studies have reported on knee ligament injuries as part of providing epidemiological data on overall injuries. Most studies have used time loss as the definition of injury, but only a few studies have reported the injury rate as the number of injuries per 1,000 h. This is a limitation of previous studies, meaning that exposure is not taken into account. Overall, the proportion of knee injuries in relation to total injuries has been reported to vary between 10%-30%[10, 50]. The injury rate for knee ligament injuries overall has been reported to range between 0.2 and 2.5 per[13, 31] 1,000 hours of exposure. There is limited data on the injury rate for specific knee ligament injuries, except for ACL injuries. The ACL injury rate has been reported to range between 0.04 and 0.076 injuries per 1,000 h[13, 90]. Two studies have reported that MCL injuries constitute the largest part of the overall injury burden[13, 107]. A summary of findings on knee injuries in other cohorts is presented in Table 1.

TABLE 1. Epidemiological data on knee injuries on male professional football

Study	League/ tournament	Study period	No. of players	No. of teams	Injury definition	Key findings on knee injuries
Árnason et al.[11]	Icelandic elite football league	1999 (1 season, 52 matches which was 46% of all matches played during the season)	Not reported	17	Time-loss injury	– 10% of all injuries (5 of 52) were knee injuries, 4 were ligament sprains and 1 knee contusion.
Árnason et al.[10]	Icelandic elite football league	1999 (1 season)	306	9	Time-loss injury	– 15.0% of all acute injuries during matches were knee injuries, while 15.2% of all acute injuries during training were knee injuries. – The total knee injury rate was 0.6 ± 0.1 injuries per 1,000 h.
Björneboe et al.[14]	Norwegian first league	2002-2007 (6 seasons)	Not reported	14	Time-loss injury	– A total of 137 knee ligament injuries were recorded (95 MCL, 16 LCL, 20 ACL, 6 PCL). – The ACL injury rate was 0.04 (95% CI 0.02-0.06) per 1,000 h. – The match injury rate for any type of knee injury was 2.2 (95% CI 1.4-3.1) during the pre-season and 2.5 (95% CI 2.1-3.0) during the competitive season.
Eirale et al.[32]	Qatar Stars League	2008-2009 (1 season)	230	10	Time-loss	– The knee injury rate in matches was 0.2 per 1,000 h, while it was 0.3 per 1,000 h in training. – The mean lay-off time for match injuries was 77.7±69.5 days, while it was 58.5±63.8 days for training injuries.
Falese et al.[47]	Italian Serie A	2012-2014 (2 seasons)	Not reported	20	Time-loss	– 19.0% of all injuries were knee injuries (69/369).
Gouttebarge et al.[52]	Australian A-league	2008-2013 (5 seasons)	184-253	10	Time-loss	– 29.8% of all injuries were knee injuries over the study period (252/845). – No. of time-loss knee injuries per team (25 players) ranged from 3.8 -7.7 per season.
Hawkins et al.[57]	Professional English leagues (Premier League, The Championship, League One, League Two)	1997-1999 (2 seasons)	2,376 players	91	Time-loss	– 17% of all injuries were knee injuries during the study period (1,014/6,030).
Hägglund et al.[55]	Danish and Swedish first leagues	Danish: Jan-Jun 2001 Swedish: Jan-Oct 2001	Danish: 188 Swedish: 310	Danish: 8 Swedish: 14	Time-loss	– 21% (81/395) of all injuries were knee injuries in the Danish spring season. – 15% (72/481) of all injuries were knee injuries in the Swedish spring season and 17% (39/234) during the autumn season. – There were significantly more knee injuries in Denmark compared with Sweden during the spring season (p = 0.032).
Klein et al.[67]	German Bundesliga and 2 Bundesliga	2014-2017 (3 seasons)	1,449	36	Time-loss and/or seeking medical attention	– 15.2% of all injuries were knee injuries. – Mean lay-off for knee injury 22.5 (55.0) days
Morgan et al.[83]	Major League Soccer	1996 (1 season)	237	10	Time-loss injury	– 21% of the injuries occurring during the season were injuries to the knee (54 knee injuries of 256).
Rekik et al.[93]	Qatar Stars League	2013-2018 (5 seasons)	324-527	10-17	Confirmed by MRI and causing time-loss	– 37 ACL injuries were recorded over 5 seasons. – The overall ACL injury rate was 0.076 per 1,000 h (95% CI 0.053-0.104).
Stubbe et al.[98]	Dutch Premier Soccer League	2009-2010 (1 season)	217	8	Time-loss injury	– 21.3% of all injuries were knee injuries (61/286).
Waldén et al.[109]	Swedish first league	2001 (1 season, including pre-season)	310	14	Time-loss injury	– 16% of all injuries were knee injuries (111/715). – Isolated MCL injuries were the most common knee ligament sprain, constituting 54% (21/39) of all knee sprains.
Waldén et al.[113]	European professional football and Swedish first league	2001-2009	European professional football n=1,367; Sweden n=652	57	Time-loss	– European professional football: 43 ACL injuries occurred (0.7% of all injuries). The ACL injury rate was 0.060 per 1,000 h (95% CI 0.44-0.80). – SWE: 20 ACL injuries occurred (0.8% of all injuries). The ACL injury incidence was 0.061 per 1,000 h (95% CI 0.039-0.094).

MCL medial collateral ligament, *LCL* lateral collateral ligament, *ACL* anterior cruciate ligament, *PCL* posterior cruciate ligament
SWE Sweden

Anatomy and function of the knee joint

The knee joint is one of the largest and most complex joints in the human body, providing both mobility and stability to the lower extremities at the same time[76]. The joint has two articulations, the tibio-femoral and the patello-femoral, which are formed by the articulation between the femur and the tibia and the femur and the patella, respectively. This construction enables extension and flexion of the joint and allows for several degrees of rotation[54]. Another important component of the knee joint is the cartilage that facilitates load transmission, which is provided in a synergistic manner with the menisci[18]. The two half-moon shaped menisci are composed of fibrocartilage and are located intra-articularly between the femur and tibia, one on the lateral side and one on the medial side[47]. The menisci are also important for providing knee joint stability[81]. The main passive stability is, however, provided by the strong knee joint ligaments, supporting the joint and preventing excessive movement of the joint during functional activities.

The cruciate ligaments are intra-articular and are named after their anatomic relationship of crossing each other like the letter X in the centre of the joint. The ACL originates on the medial side of the lateral femoral condyle and runs anterodistally through the knee joint to its insertion site at the medial tibial eminence[85]. The ACL is described as a single ligament, although it is in fact composed of two separate bundles[72]. A partial ACL injury could therefore occur if only one bundle is ruptured and a complete ACL injury refers to the rupture of both bundles. The PCL is located just behind the ACL and originates at the medial femoral condyle, while inserting at the back of the tibia[106]. The primary function of the cruciate ligaments is to provide anteroposterior and rotational stability[72]. The collateral ligaments are extra-articular and are located on the medial and lateral aspect of the knee joint respectively. The MCL and LCL are therefore the primary stabilising structures when it comes to forces in these directions, which can also be described as valgus and varus forces. With regard to the MCL, the ligament has one superficial and one deep part[22, 68] and it stretches from the outer aspect of the medial femoral epicondyle to its distal insertion on the tibia close to the pes anserinus[70, 75]. The deep fibres of the MCL are attached to the medial meniscus, entailing a high risk of concomitant medial meniscus injury when the MCL is torn[75]. The LCL is located on the lateral aspect of the knee joint, originating on the lateral femoral epicondyle and inserting to the fibular head after converging with the biceps femoris tendon[44, 96]. The LCL, however, has no attachment to the lateral meniscus, as opposed to the MCL and medial meniscus. Because of the more mobile lateral meniscus, compared with the medial one, the lateral meniscus is exposed to a lower injury risk during non-contact pivoting mechanisms in football.

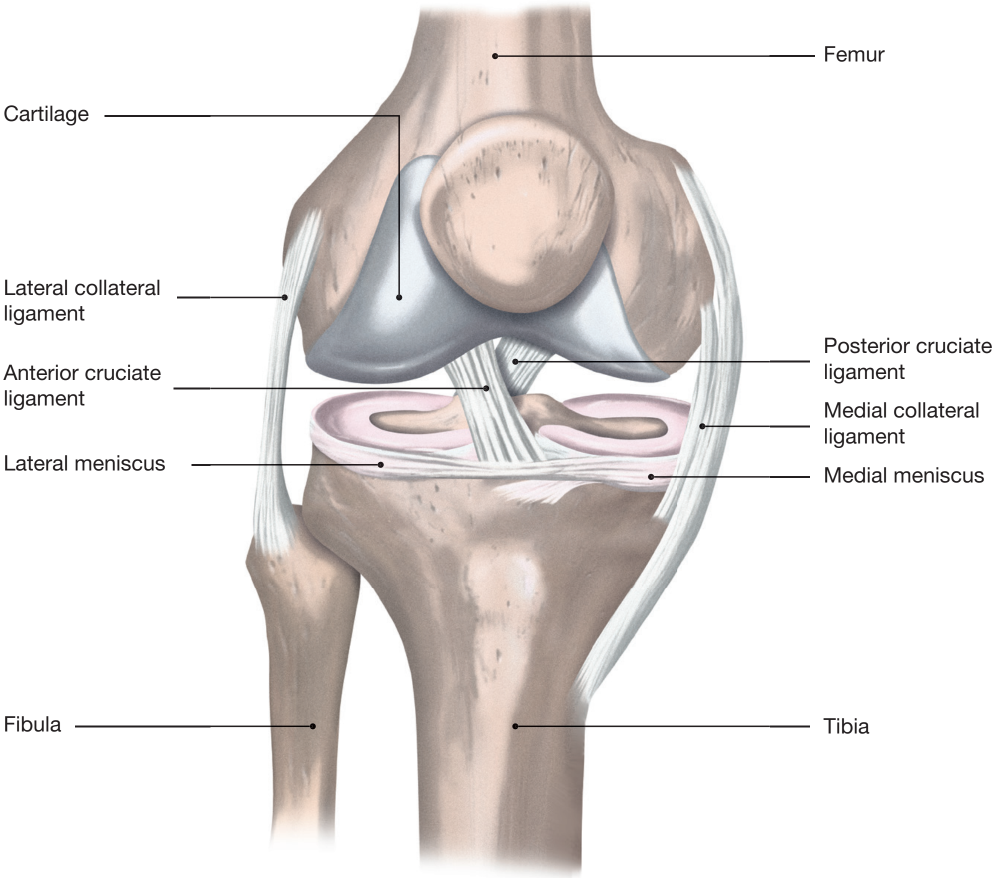

FIGURE 4. Anatomy of the knee with the collateral ligaments and cruciate ligaments which are essential for knee stability.

INJURY MECHANISM AND RISK FACTORS

The different functional properties of the knee joint ligaments mean that the situations in which injuries tend to occur differ between the knee joint ligaments. In general terms, a ligament injury occurs when excessive forces are applied to the ligament, exceeding its restraining capacity. Once injury mechanisms are identified, training programmes can be implemented in susceptible populations, like professional football players, to reduce the injury risk and avoid the long-term consequences associated with knee ligament injuries. The medical teams at all elite clubs strive to prevent injuries. One way to prevent injuries from occurring is to identify risk factors in order to stay away from the risks or to train in a certain way to cope with the risk without being injured. It is also very important for the medical teams and sports scientists to pay extra attention to players who are exposed to the identified risk factors and to take action to minimise the injury risk.

Fatigue and injury risk

Playing a game of football affects the internal metabolic and physiological load and causes fatigue both temporarily and towards the end of a game. The repeated intense use of muscles leads to a decline in performance known as muscle fatigue. Fatigue in a muscle results in an inability to produce force or power[43] and, when a fatigued muscle is used to perform a maximum contraction, the rate of fatigue is the same as the decline in performance. In football, however, most actions involve submaximum contractions. In these situations, fatigue does not limit the ability to perform the action, but it may affect the quality of the movement in terms of precision and co-ordination. The contribution to these alterations in movements is thought to be derived from the complex interaction between both the central and peripheral nervous system. Central fatigue is defined as limiting processes inside the spinal cord and above, while peripheral fatigue is defined as limiting processes in the peripheral nerves, neuromuscular junction and muscles[2].

Interestingly, several studies have shown that the total distance of high-intensity running (HIR) activity and sprinting is significantly lower in the second half compared with the first half in a football game and this decrease is even more pronounced in the last 15 minutes of a game[14-16, 79]. These findings suggest that a player's performance capacity is reduced at the end of the games when fatigue has a maximum impact and there is a need to establish whether this is associated with an increased injury rate at the end of a game. In theory, both central and peripheral fatigue could contribute to a higher injury risk at the end of a game. It is possible that less muscle strength is important for knee joint stability and could lead to alterations in kinematics and potentially increase loads on the knee joint ligaments when the active stabilising muscle function is compromised. Neuromuscular fatigue could also reduce co-ordination and precision in tackling situations and impact cognition and decision-making when a player is entering a contact situation, impacting the risk of injury sustained via a contact mechanism. However, there is limited research on the association between the timing of injuries during a game and knee ligament injuries in male professional football. Studies of fatigue suggest that, if fatigue is an injury risk factor, it is probably more an effect of accumulated fatigue over time, owing to a congested match calendar, for example, than energy depletion per se in the match in which the ACL injury occurs[21, 29]

ACL injury

An ACL injury may occur when an anterior load caused by excessive tibial translation is applied. This kind of mechanism could, for example, occur when a player lands on a stiff knee in hyperextension and a strong quadriceps muscle force is generated, thereby translating the tibia anteriorly[25]. Combined anterior and rotatory forces causing an ACL tear are, however, the most common injury mechanism, which, in the vast majority of all ACL injuries in professional football, occurs in a non-contact situation[110]. These situations commonly include pivoting movements, cutting manoeuvres or decelerations[1], which, coupled with tibial anterior translation, valgus collapse and external tibial rotation, cause the ACL to rupture[25, 112]. In male professional football, it has been stated that there is a higher risk of a new knee injury with a previous ACL injury[109]. It has also been reported that ACL injuries in professional football tend to occur early in the first half or among newly substituted players in the second half[110]. There is also a higher risk of ACL injuries in matches compared with training and one study reported that the match-play ACL injury rate is 20 times higher than the training injury rate[113]. Since it has been reported that a previous injury is a strong risk factor for sustaining a new injury after return to play among male professional football players[9, 30, 42], it is possible that a prior injury of any type would also increase the risk of sustaining an ACL injury. The way a prior injury affects the risk of sustaining an ACL injury in male professional football has, however, not been studied.

PCL injury

A PCL injury is often referred to as “a dashboard injury”, describing the mechanism of PCL injury in motor vehicle accidents, when a posterior force is directed at the tibia with the knee in flexion, due to the sudden impact of the dashboard in a collision. The mechanism of a direct blow to the tibia when the knee is flexed and the ankle is in plantar flexion is the most common injury mechanism for a PCL injury[93]. However, it may also be caused by coupled hyperextension and rotatory or valgus/varus movement[73]. It has been reported that the most frequent injury mechanism in athletes is knee hyperflexion[46, 73]. PCL injuries have been studied on a very small scale in professional football; one possible explanation is that the injury is uncommon. One study, performed on professional football players in a newly established third German football league, reported that the incidence of cruciate ligament injuries (both ACL and PCL included) increased during the pre-season and that players who had played at a lower level in the previous season sustained the majority of the injuries[66].

Collateral ligament injuries

An MCL injury is commonly sustained in contact situations, when a direct trauma on the lateral aspect of the knee causes an excessive valgus movement[75]. Another possible mechanism of injury is a pivoting movement producing excessive valgus stress in combination with tibial internal rotation[75], which resembles the ACL injury mechanism. This type of mechanism leads to a high risk of suffering a combined ACL and MCL injury[41]. Some risk factors for MCL injury have not been studied in male professional football. It is likely that MCL injuries share risk factors described for other contact injuries and that risk factors such as match play and previous injury are important. To understand the epidemiology of risk factors for MCL injury, there is a need for more research. The common injury mechanisms for LCL injury include a direct blow to the anteromedial knee, varus force or hyperextension[55, 69, 92]. LCL injury seldom occurs in isolation and is most often accompanied by other ligament injuries. It may also be part of a more severe injury to other structures of the posterolateral corner of the knee[71, 77]. The training and match injury rates for MCL and LCL have not been studied.

RETURN TO PLAY AND TREATMENT

'When can I play again?' This is the first question you will be asked as a physician or physiotherapist by an injured player. The team physician will consequently, after obtaining consent from the player, be asked to communicate a prognostic time for return to sport (RTS) to the team supporting the players, such as the coaching staff, the physical trainers, the sports scientists, monitoring the load and to the media. Answering this question accurately is difficult due to the lack of literature that provides data for the estimation of RTP, i.e. lay-off time, for specific knee ligament injuries in professional football. This can lead to the team physician either not being able to give a prognosis for RTP or being forced to rely on his or her clinical experience to estimate the time to RTP. However, RTP is a complex and multifactorial process and efforts to reach consensus on this process have been made in order to create a standardised approach to the assessment of readiness to RTP[6, 7]. RTS is a continuum and RTS should be distinguished from RTP, which means that a player is able to participate in training and be fully available for game selection without restriction. RTS should, however, be allowed earlier to give the player a gradual increase in training load and can include training on the pitch with a ball but without situations risking contact with another player. When a player sustains an ACL injury, for example, the RTP estimate from the team physician can be approximately seven months, based on a study showing that the median lay-off for an ACL injury in professional football male professional players who underwent ACL reconstruction was 6.6 months to training and 7.4 months until the player played his first match[113].

One year after an ACL reconstruction, most players have returned to play at the same playing level[110]. This is not the case after three years, when 45%[113] of the players are no longer active at the same playing level, despite great economic incitements for the player in the form of a high salary and possible private brand at this level. There is insufficient data on how many players RTP after other types of knee ligament injury.

Both MCL[22] and LCL injuries do not most commonly require surgical treatment and they are therefore usually deemed as moderate injuries. The majority of isolated grade I and II MCL injuries are treated with physiotherapy and sometimes a stabilising knee brace, while grade III injuries sometimes require surgical intervention with a ligament repair or reconstruction[22]. There is, however, no high-quality evidence in the literature supporting the stabilising knee brace as a beneficial treatment method for MCL injuries. Another treatment method which lacks supporting high-level evidence for MCL injuries, other than emerging evidence in rabbit models in the early phase of healing, is plasma-rich injections (PRP)[99, 118]. On the other hand, ACL and PCL[51] injuries in most players require surgical treatment and therefore result in a longer rehabilitation period and lay-off. The typical advice for athletes wanting to return to pivoting sports such as football after an ACL injury is an ACL reconstruction followed by structured rehabilitation[48], especially at elite level.

2 RATIONALE FOR THIS THESIS

02

RATIONALE FOR THIS THESIS

In order to improve and prevent injuries, it is firstly important to evaluate current practice and acquire knowledge in terms of the epidemiology and the characteristics of injuries that football clubs are facing. Having a player sustain a knee ligament injury could be devastating for a club and not the least for the player. In the worst case, a knee ligament injury may threaten the player's future career. Despite the fact that the available literature highlights the need for preventive measures and interventions to counter injury rates in the athletic population, there is a limited number of prospective studies investigating the epidemiological characteristics of knee ligament injuries specifically in football. This is a paradox considering that football is regarded as the largest sport in the world and it is likely that the injury panorama differs between specific sports. Moreover, the available studies on knee ligament injuries in male professional football have most commonly studied knee ligament injuries as a common group and the majority of the research has focused on the ACL. Less is known about the epidemiology and more research on return to football for injuries to the MCL, LCL and PCL is needed.

3 AIM

AIM

GENERAL AIM

The aim of this thesis is prospectively to study and describe the epidemiology and characteristics of knee ligament injuries in men's professional football and to identify risk factors for knee ligament injuries with specific emphasis on MCL injuries.

SPECIFIC AIMS

Study I To investigate the rate and circumstances of MCL injuries and time trends in injury rates over multiple seasons.

Study II To describe the epidemiology and injury mechanisms for MCL injuries. Secondly, the study aimed to evaluate diagnostic and treatment methods for MCL injuries and to study the agreement between clinical and MRI assessment for the severity grading of MCL injuries.

Study III To analyse whether the risk of sustaining an ACL injury increases after return to play from any injury other than an ACL injury

Study IV To investigate the rate and circumstances of PCL and LCL injuries and the development of LCL injury incidence over the past 17 years

04

METHODS

The majority of the material in the present thesis originated from the UEFA ECIS (Elite Club Injury Study), which was originally termed the UEFA Champions League Injury Study[108]. Data from the UEFA ECIS cohort from 2001 to 2018 (17 seasons) were included in the current thesis. Additionally, data from the English Premier League (EPL) between 2011 and 2014 (3 seasons) were included and, in Study III, data from the Nordic Football Injury Audit (NFIA) were also included. The NFIA consists of teams from the Swedish and Norwegian Premier Leagues and, in the present thesis, data between 2010 and 2011 (two seasons) were included. The cohorts included in specific studies in this thesis are listed in Table 2.

All the cohorts followed the same data collection procedures and study design. An overview of the participating teams in each season is provided in Appendices 1 and 2. At the beginning of 2019, the UEFA ECIS database comprised data from a total of 68 European top-level football teams comprising 4,389 individual players from 19 European countries. The establishment of the UEFA ECIS dates back to 1999, when, commissioned by the UEFA President Lennart Johansson, the UEFA Medical Committee initiated a research project aiming to reduce the number and severity of injuries in male professional football players and increase player safety[56]. A consensus meeting was held within the UEFA Medical Committee in order to establish the methodological aspects of the study and the first studies were initiated according to the study protocol in 2001[56]. Since then, research based on the study cohort has covered a wide range of research topics with the aim of both increasing the safety of players who participate in competitions organised by UEFA and contributing to a better understanding of the consequences and causes of injuries in football[24]. The qualifying stage and play-off for the UEFA Champions' League group stage finishes at the end of August each year and all the teams reaching the group stage of the UEFA Champions League are invited to participate in the UEFA ECIS. In addition, teams that have already been included in the UEFA ECIS are automatically offered the chance to participate the subsequent year, even if the team does not qualify for participation in the UEFA Champions League. Moreover, teams which were among the best 50 teams in Europe, according to the UEFA club coefficient ranking, are also considered eligible for inclusion in UEFA ECIS. The UEFA club coefficient ranking is based on the results of the clubs, and other clubs from the same association, in European competitions over the last five seasons[100]. The EPL consists of 20 teams which all play against each other twice a season. The pre-season comprises around five to six weeks and the season starts in mid-August. After the season has ended around mid-end May, all the EPL teams are invited to participate in the EPL cohort. Allsvenskan, the men's first league in Sweden and the Norwegian men's first league, Tippeligaen, each comprise 16 clubs. In each league, each club plays two matches against one another every season. In both Allsvenskan and Tippeligaen, the pre-season starts in early January and the competitive season begins from mid-March/early April and runs until mid-November.

TABLE 2. Cohorts included in specific studies comprising the current thesis

	UEFA ECIS	NFIA	EPL
Study I	X		
Study II	X		X
Study III	X	X	X
Study IV	X		X

ECIS, Elite Club Injury Study; *EPL*, English Premier League; *NFIA*, Nordic Football Injury Audit

Data collection and study design

The UEFA Medical Committee consensus meeting resulted in the establishment of a standardised data collection process including definitions of how and when data should be collected, which data should be included and how they should be defined[56]. In the current thesis, a prospective data collection design was implemented in order to avoid biases associated with a retrospective study design, in particular, recall bias. A prospective study design also enables the control of exposure time in a prospective manner, which is important, as playing time can vary greatly between players in a team and is a relevant factor that can influence the injury risk.

The data collection is based on three important elements; baseline data, exposure data and injury data. Three standardised forms have been developed to ensure similar and structured data collection among the clubs. The data are collected by one appointed contact person at each club, who is responsible for completing and sending the study form to the research staff of the cohorts. In order to accurately record individual exposure in the UEFA studies, a criterion for filling in the attendance record (exposure form) was that the person responsible should be available at all training sessions and matches. It was decided that a member of the medical team, team doctor or physiotherapist, should ideally be responsible for filling out the forms and forwarding them to the study group. The reports are sent to the research team by the appointed person in the clubs at the end of each month. All contact persons receive a study manual at the beginning of each season with detailed instructions on the methodology of data registration and definitions of the variables of interest in the study. The manual contains information about how to complete the study forms. Members of the study group are in frequent communication with all contact persons for the teams during their participation in the cohorts. They are encouraged to communicate with the study group when they are unsure about how to complete the forms. Extra guidance is often needed during the first season of participation in the cohorts and explanations of procedures are provided by the study group either in person or via e-mail or phone.

Baseline form

The baseline form is completed once a year, at the beginning of each season or as soon as possible when a player is recruited to a team during an ongoing season, and includes demographic data in terms of age, weight, height, dominant leg (kicking leg) and playing position. This form is also used to obtain the informed consent of the participating player (Appendix 3).

Exposure form

The exposure form includes information on playing and training time, which is used to evaluate "time at risk of an injury". This is important since the training and, perhaps even more so, the match exposure can vary substantially among players and a player with a higher attendance in training and matches has more time at risk of sustaining an injury compared with a player with less attendance. The basic exposure form includes a list of players' names and specific study code numbers used to identify players included in the cohort, together with a column for each training session and match in which participation is recorded individually in minutes (Appendix 4). On the exposure form, information on all the football activities (minutes of exposure) of the listed player is registered, including any national team training sessions and matches and matches with, for example, reserve and U21/23 team matches.

Injury forms

The general injury form includes sections for reporting on the date of injury, whether the injury occurred during training or match play, the injury type, location and a measurement of injury severity (Appendix 5). The Orchard Sports Injury Classification System-10 (OSICS-10)[87] was used to classify specific injuries in the databases of the cohorts. The OSICS is one of the most commonly used injury classification systems for coding injuries in sports injury surveillance[83]. As part of the continuous feedback from clubs and the internal development of the UEFA ECIS, there have been a few additions of requested data on the injury form over the years. For example, contact/non-contact injury was added from the 2004/2005 season, match minute of injury from the 2005/2006 season and injury mechanisms from the 2008/2009 season.

For several football-relevant injury subtypes, such as ACL injuries[110], hamstring injuries[38] and fifth metatarsal fractures[37], the general injury form was complemented by a second sub-study specific injury form. At the end of each month, when the injuries are reported on the general injury forms, the additional sub-study specific injury form is immediately sent to the clubs in which players have suffered sub-study specific injuries. A similar sub-study specific card for MCL injuries was used for Study II (Appendix 6).

Inclusion criteria

At professional level, the number of contracted players typically consisted of approximately 25 players[36], but lately squad sizes appear to have increased, with larger between-club variations. A methodology for limiting the number of eligible players on the squad list for the injury study might introduce selection bias and it was therefore decided at the consensus meeting that all players with a first-team contract should be included. This also includes players with ongoing injuries. An injured player at the start of the season should thus be included, but that particular injury should not be included in the injury statistics and the exposure should not be counted until the player is fully cleared to return to play.

Study period

Injury risk and patterns vary over the football season[115] and the study period should therefore include the entire season, or several seasons, including both the pre-season and the competitive season. For the professional clubs participating in the UEFA ECIS and EPL, the pre-season usually starts in July and ends in mid or late August. The competitive season follows immediately after the pre-season and ends in May (dates vary and are mainly dependent on whether there is an international championship such as the FIFA World Cup or European Championship in the off-season summer period).

Injury definitions

As part of reaching consensus on a standardised methodology for data collection and reporting, the UEFA Medical Committee also decided how an injury should be defined. A definition of this kind is important in order to obtain a homogeneous cohort of injured players and to optimise comparative analyses of injured players. The committee reached consensus on defining an injury according to time loss, i.e. a player should be regarded as injured if he sustains any physical injury during training or a match that prevents him from participating in at least one training session or match. This definition means that minor physical complaints that might lead a player to seek medical attention but do not lead to time loss from football are excluded. Moreover, it does not require a specific confirmation of the type of structural injury, which many times needs to be determined clinically or by imaging modalities. The time-loss definition of injury is intended to reflect the most relevant information for clinicians, players and coaches in professional football, that is, the effect of an injury in terms of time away from football. All the studies included in the present thesis therefore followed the time-loss definition of injury. Consequently, a player was injured by definition until the team's medical staff allowed full participation, i.e. RTP, in team training and availability for first team match selection. A summary of the operational definitions used in the UEFA ECIS is given in Table 3.

TABLE 3. Operational definitions used in the current thesis[49, 56]

Training session	Team training that involves physical activity under the supervision of the coaching staff
Match	Competitive or friendly match against another team
Injury	Injury resulting from playing football and leading to a player being unable to participate fully in future training or match play (i.e. time-loss injury)
Rehabilitation	A player is injured until the team medical staff allow full participation in training and availability for match selection
Re-injury	Injury of the same type and at the same site as an index injury occurring no more than two months after a player's return to full participation from the index injury
Slight injury	Injury causing 0 days' absence from training and match play
Minimal injury	Injury causing 1-3 days' absence from training and match play
Mild injury	Injury causing 4-7 days' absence from training and match play
Moderate injury	Injury causing 8-28 days' absence from training and match play
Severe injury	Injury causing more than 28 days' absence from training and match play
Non-contact injury	Injury occurring without any contact with another player or object
Contact injury	Injury occurring with contact with another player or object
Injury rate	Number of injuries per 1,000 player hours [(Σ injuries/Σ exposure hours) × 1,000]
Injury burden	Number of lay-off days per 1,000 player hours [(Σ lay off days/Σ exposure hours) × 1,000]

Knee ligament injuries are traumatic, so 'a traumatic distraction injury' is used in the definition of knee ligament injuries in the present thesis. The time loss, i.e. a player being unable to participate fully in training or match play, corresponds to the UEFA ECIS definition of injury (Table 4).

TABLE 4. Knee ligament injury definitions used in the current thesis

MCL	A traumatic distraction injury to the superficial MCL (sMCL), deep MCL (dMCL) or the posterior oblique ligament (POL), leading to a player being unable to participate fully in training or match play
LCL	A traumatic distraction injury to the LCL leading to a player being unable to participate fully in training or match play
ACL	First-time complete rupture of the ligament occurring either in isolation or in association with other concomitant injuries to the knee joint
PCL	A traumatic distraction injury to the PCL leading to a player being unable to participate fully in training or match play

Injury severity

Another important aspect is the classification of injury severity, which should preferably be stratified according to the time loss. Nonetheless, the way cut-off values for time loss in relation to injuries severity are categorised differs in earlier studies[56]. The UEFA consensus discussions[49] initially agreed on classifying injury severity into mild (1-7 days' absence), moderate (8-28 days' absence) and severe (>28 days' absence)[56]. In the broader consensus statement publication from 2006, it was decided that, if a player is unable to participate fully on the day of an injury but is available for full participation the next day, the incident should be recorded as a time-loss injury with a severity of zero days[49]. In addition, injuries with an absence of up to a week were divided into two categories: minimal (1-3 days' absence) and minor (4-7 days). The consensus statement classification of injury severity was implemented in the UEFA ECIS from the 2006/2007 season.

Specific methodology for the present thesis

Specifically in this thesis, four separate studies of knee ligament injuries in men's professional football were conducted. An overview of players and the objective of each study are provided in Table 5. The specific methodology for each study is presented under separate sub-headings below.

TABLE 5. Overview of the material and aim for each study in the present thesis

Study	Teams (n)	Players (n)	Seasons (n)	Ligament	Study aim
I	27	1,743	11	MCL	Circumstances of injury and injury rate over time
II	51	2,018	3	MCL	Injury rate, injury mechanism, the diagnostic and treatment methods, the agreement between clinical and MRI grading
III	45	202	12	ACL	Risk of subsequent ACL injury after return to play from any other injury
IV	68	4,389	17	LCL	Circumstances of injury and injury rate over time
				PCL	Circumstances of injury and injury rate

ACL anterior cruciate ligament, *LCL* lateral collateral ligament, *MCL* medial collateral ligament, *PCL* posterior cruciate ligament, *MRI* magnetic resonance imaging

Study I

For the purpose of this study, 27 European teams (1,743 players) were followed for 11 seasons between 2001 and 2012. This study used data provided by the baseline form, the exposure form and the injury form in order epidemiologically to describe the rate of MCL injury, the seasonal variation in injury rate,and the circumstances of sustaining an MCL injury and the over-season variation in injury rate in men's professional football. For this specific study, data from the baseline form were used to determine the injury rate according to the dominant and non-dominant leg. Data on the total exposure time for the cohort in matches and training were obtained from the exposure form and these data were combined with data obtained from the injury form to determine the injury rate and injury burden for MCL injuries. The injury form also enabled an epidemiological description of circumstances when the MCL injuries were sustained, i.e. in what type of situations and when during a match the injury was sustained. Additionally, the lay-off time was analysed according to the injury severity definitions used in the UEFA ECIS.

Study II

For the purpose of this study, 51 teams with 2,018 individual players from the highest national leagues in 17 European countries were followed for between one and three seasons between July 2013 and May 2016. When an MCL injury was reported as the main diagnosis on the general injury form, an additional study-specific MCL injury form (Appendix 6) was sent to the team's medical staff requesting details on previous knee ligament injuries, clinical grading, imaging findings and specific treatment details.

The MCL injuries were categorised into three different severity grades based on findings during clinical examination and magnetic resonance imaging (MRI). Only clinical and MRI grading were used for analyses in this study. The clinical grading system on the MCL injury form was based on the medial joint opening during the valgus stress test in semi-flexion and full extension[55]. There was no predefined order in which the MRI or clinical grading of MCL injuries was performed.

In Study II, which is a sub-study to the UEFA ECIS, the injuries were classified according to clinical and MRI grading (grades I-III), Table 6.

TABLE 6. MCL clinical injury grading and MRI grading

MCL injury grading	
Clinical grade I	Tenderness on palpation or pain during stress test but no or only minimally increased laxity
Clinical grade II	Increased laxity during stress test with semi-flexion, but not in full extension
Clinical grade III	Gross laxity during stress test with semi-flexion and increased laxity also in full extension
MRI grade I	Oedema/haemorrhage within or surrounding the ligament but intact fibres
MRI grade II	Partial ligamentous disruption but with continuity and some intact fibres
MRI grade III	Complete ligamentous disruption or osseous avulsion, discontinuity and virtually no intact fibres

Study III

This study was designed as a case-control study and comprised 101 male professional football players who suffered a first-time total ACL injury. The ACL-injured players and their matched controls came from 45 professional football teams from the top divisions in 11 European countries. The players were randomly matched (1:1 match) against 101 control players without an ACL injury. Each control was matched from the same team as the injured player, as the players in the same team have similar training activities, injury-prevention strategies, quality/type of pitches and rehabilitation strategies. The injured players and controls were also matched according to playing position (defender and midfielder/forward) and age (± 3 years). It was decided that players who constituted the ACL-injured group should only be included if the identified ACL injury was the first ACL injury a player had sustained. As a result, all players who had a history of a previous ACL injury were excluded. The same criterion was applied to the control group; if a player had a history of a previous ACL injury, he was not eligible for inclusion in the control group. The ACL injuries (complete ACL tear), as determined by clinical investigation, MRI and/or surgery, which had been recorded prospectively during the injury surveillance were included. Partial ACL injuries were excluded. Goalkeepers were also excluded from this study. The injured players and paired controls were studied during the same 90-day period, where the controls required full exposure (participated in all training sessions and matches).

Study IV

Specifically in this study, 68 European teams (4,389 players) were followed for 17 seasons between 2001 and 2018. Like Study I, this study used data provided by the baseline form, the exposure form and the injury form in order to epidemiologically describe the rate of LCL and PCL injuries, the seasonal variation in LCL injury rate and the circumstances of sustaining a LCL or PCL injury in men's professional football. For this specific study, data from the baseline form were used to determine the injury rate according to the dominant and non-dominant leg. Data on the total exposure time for the cohort in matches and training were obtained from the exposure form and these data were combined with data obtained from the injury form to determine the injury rate and injury burden for LCL and PCL injuries . The injury form also enabled an epidemiological description of circumstances when the LCL and PCL injuries were sustained, i.e. in what type of situations and when during a match the injury was sustained. Additionally, the lay-off time was analysed according to the injury severity definitions used in the UEFA ECIS.

5 ETHICAL APPROVAL

05

ETHICAL APPROVAL

The study protocol for the UEFA ECIS was reviewed and approved by the UEFA Medical Committee and the UEFA Football Development Division prior to study start. In Study III, in which teams from the Swedish and Norwegian first leagues participated, additional ethical approvals were obtained from the Local Ethics Committees in Linköping, Sweden (Dnr: M240-09), and Region Øst-Norge and the Norwegian Social Science Data, Norway (S-06188). All studies were conducted according to the World Medical Association Declaration of Helsinki statement. This states, for example, that all participation is voluntary for the players and that the players can withdraw from participation at any time. Prior to study participation, the players are provided with information about the study and written informed consent is obtained. To protect the integrity of the participating players, each player is given a study-specific ID number that is used throughout the data collection and data analysis.

6 STATISTICAL METHODS

STATISTICAL METHODS

Descriptive statistics were presented as the mean and standard deviation (SD), as well as the median with range and quartiles (Q1=25th percentile and Q3=75th percentile). Categorical variables were presented as count and percentages. All analyses were performed using SAS software version 9.4 (SAS Institute Inc, Cary, NC, USA) or SPSS (IBM SPSS Statistics for Windows, Version 24.0, Armonk, NY, USA: IBM Corp.). All tests were two-sided and the significance level was set at $p < 0.05$.

The statistical methods used in each study are presented under specific sub-headings as follows and a summary of statistical methods by study is presented in Table 7.

Study I

Group differences in lay-off time were analysed using the Mann-Whitney U test due to the skewed distribution in lay-off time. Pearson's $\chi 2$ test was used to analyse the association between categorical variables. Group comparisons of injury burden and injury rates were calculated as the rate ratio (RR) with a 95% CI, while z-statistics[74] were used for significance testing. A linear regression model with log-transformed injury rates as the dependent variable was used to analyse seasonal trends in injury rate, expressed as the average annual percentage of change. In addition, a two-year moving average approach was used in order to smooth out large seasonal variations. A one-sample proportional z-test was used to analyse the differences in injury occurrence between 15-min periods in matches.

Study II

Between-group comparisons were carried out using the Mann-Whitney U test for continuous variables, Fisher's exact test for dichotomous variables and the chi-square test for non-ordered categorical variables. Due to the small number of patients with grade I and III MCL injuries, the use of injection therapy was only analysed and reported for grade II MCL injuries determined by MRI. Agreement between clinical grading and the MRI diagnosis of the MCL injuries was described by percentage agreement and weighted kappa with 95% CI. The following kappa cut-off values were used; ≤ 0.20 corresponds to slight agreement, 0.21-0.40 fair, 0.41-0.60 moderate, 0.61-0.80 substantial and 0.81-1 almost perfect agreement[67]. The systematic differences between the methods were analysed with the sign test.

Study III

Descriptive statistics were presented for the number of injuries, exposure, injury incidence and number of injury periods during the study period. A matched and paired case-control study was carried out, where the matched pair had at least one injury versus no injury during the 90-day period. A comparison with regard to absence from play because of injury versus no absence during the 90-day period was performed between the case and control groups. The analysis also included ongoing injury absence at the start of the 90-day period. The McNemar chi-square test was applied to analyse differences in exposure between the injured players and controls. The quartiles in the McNemar test were based on the players with an ACL injury and controls together. Consequently, the 25% of players with the lowest exposure were in the < 25% quartile and the same thing applied to the remaining quartiles.

The odds ratios (ORs) for injury and absence periods due to injury respectively were calculated with the odds for the ACL-injured group in the numerator and the odds for the control group in the denominator. The Mantel-Haenszel method was used to calculate the OR, using the 95% CI.

TABLE 7. Summary of statistical methods used in Studies I-IV.

Study	Mann-Whitney U test	Chi-square test	McNemar chi-square test	Fisher's exact test	Sign test	Binominal test	Rate ratio calculation (z-statistics)	Odds ratio calculation (Mantel-Haenszel)	Linear regression for seasonal trend	Weighted kappa	One-sample proportional z-test
I	X	X					X		X		X
II	X	X		X	X					X	
III			X					X			
IV	X	X		X		X	X		X		

7 RESULTS

RESULTS

Study I

A total of 8,029 injuries were documented during the study period, which included just over a million hours (1,057,201 h) of exposure. Of the documented injuries, 346 (4.3%) were MCL injuries. The injury rate during games was nine times higher than during training (1.31 vs 0.14/1000 h, RR 9.3, 95% CI 7.5 to 11.6, $p<0.001$). There was a decrease in MCL injury incidence over the study period. Calculating using the moving average approach, a decrease of 3% per season was shown and the log-transformed model showed an even greater annual decrease of 7% ($R2=0.46$, $b=-0.069$, 95% CI –0.125 to –0.012, $p=0.023$) (Figure 5).

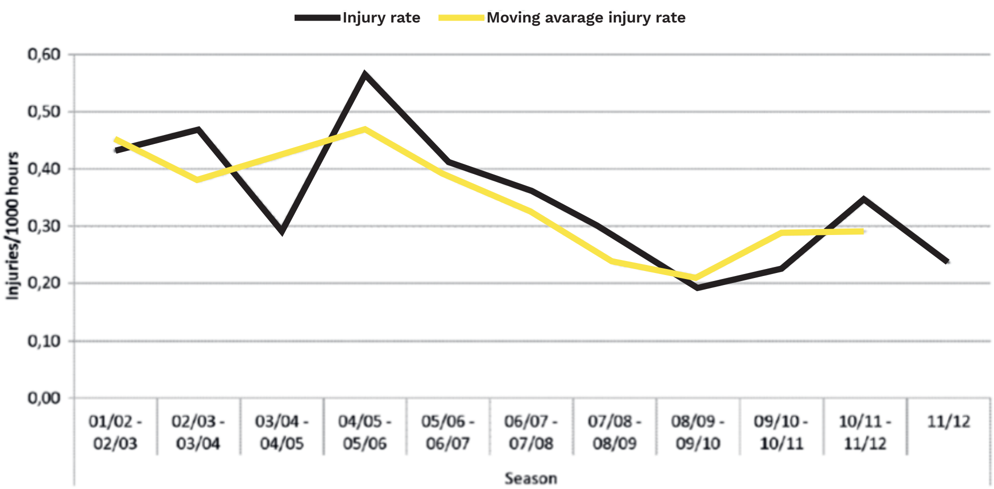

FIGURE 5. Seasonal variation in injury rates for MCL injuries in professional football

Almost seventy per cent (182/264) of all MCL injuries occurred in contact situations and players suffering MCL injuries had a lay-off time of 23 ± 23 (median=16, Q1=8, Q3=31) days, regardless of contact (median=16, Q1=8, Q3=29) or non-contact mechanism (median=16, Q1=7, Q3=30), (p=0.74). Approximately 43% of the MCL injuries occurred during the last 15 minutes of either the first or the second half (53/123), which was a significantly higher proportion (p=0.022) than would be expected (one third of all injuries occurring in each 15-minute period of a half) (Figure 6). There were no differences in the quarterly distribution between the first and second halves (p=0.76).

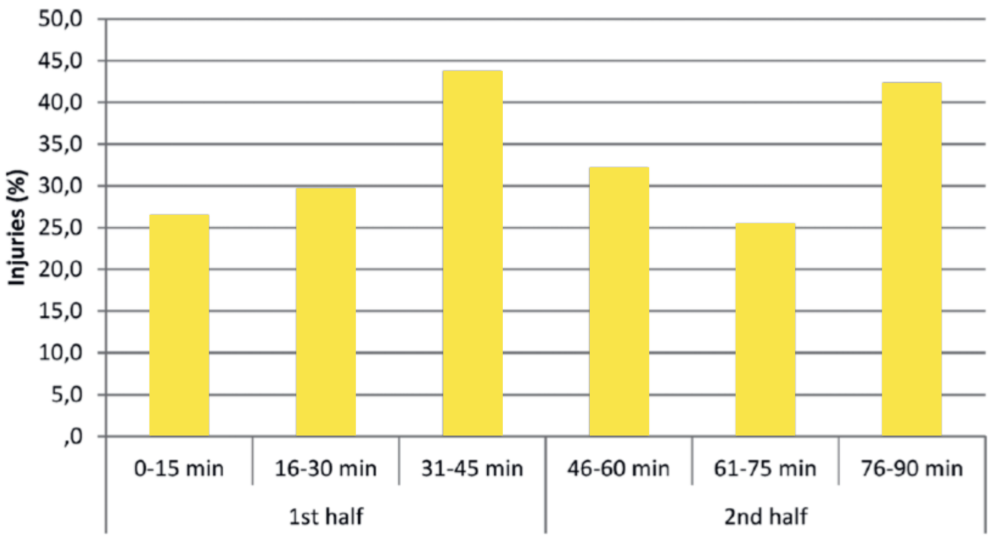

FIGURE 6. Figure displaying the proportion of medial collateral ligament injuries sustained in each half of the game, divided into 15-min periods of each half

Study II

During the three-season-long study period, 4,364 injuries were registered and 130 (3.0%) were MCL injuries in a total of 115 players. Of the 130 MCL injuries, 11 (8.5%) were re-injuries, meaning a recurrent ipsilateral MCL injury occurring within two months of returning to play. Most MCL injuries (n=98; 75.4%) occurred in contact situations and the playing situations that caused most contact injuries were when a player was being tackled (n=38; 29.2%) and when the player was tackling (n=15; 11.5%) (Figure 7).

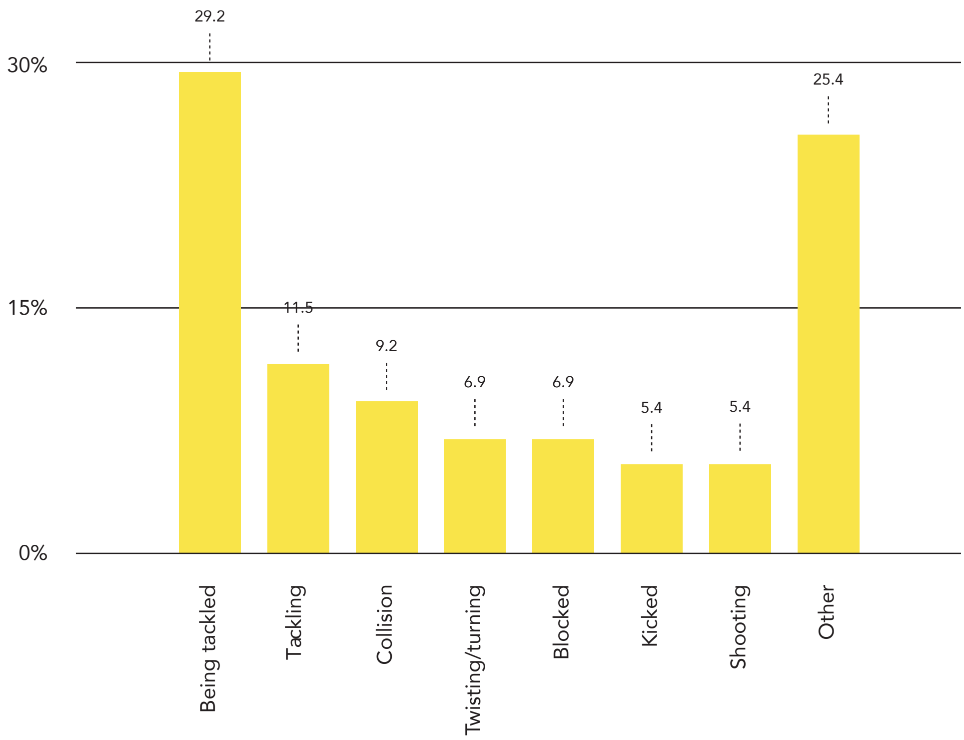

FIGURE 7. Distribution of the playing situations that caused MCL contact injuries (n=130)

The mean lay-off time for a player sustaining an MCL injury was 24 ± 22 days. A total of 74 injuries (58.7%) had an MCL injury grade I according to the clinical examination. As a result, an MCL injury grade I was the most common clinical grade, with a mean lay-off time of 10 ± 32 days. Table 8 presents the number of players for each clinical grade and additional diagnostic evaluation methods used for the cohort.

TABLE 8. Diagnostic evaluation methods and clinical grading

	Clinical grading			
	I	**II**	**III**	**Total**
Clinical examination only	32	1	0	33
MRI	29	38	4	71
US	4	0	0	4
MRI and US	7	8	0	15
Radiograph	1	0	0	1
MRI and radiograph	1	0	0	1
Arthroscopy, MRI, US	0	0	1	1
Total	74	47	5	126

Data missing from three injuries on diagnostic evaluation and one on clinical grading
MRI magnetic resonance imaging, *US* ultrasonography

Most MCL injuries were sustained in the upper third of the ligament (n=68, 54.0%), while the least common location was injury to the lower third of the MCL (n=19, 15.1%). There were no differences in the lay-off time between the different locations (Table 9).

TABLE 9. MCL injury location and lay-off time

	Upper third	Middle third	Lower third
N (%)	68 (54.0%)	39 (31.0%)	19 (15.1%)
Mean lay-off days (SD)	23±21	24±20	24±29
Missing data on four injuries			

MCL medial collateral ligament

Clinical examination alone was used to assess 33 injuries (25.4%) and imaging was used in 93 injuries (74.6%) to establish the diagnosis of the injury. Eighty-eight injuries (67.7%) were diagnosed both clinically and with MRI. An almost perfect agreement was seen between clinical examination and MRI in MCL grading (92%) (Table 10 and Figure 9).

TABLE 10. Agreement between clinical and MRI grading of MCL injuries

	MRI grading			
Clinical grading	**I**	**II**	**III**	**Total**
I	33	4	0	37
II	2	43	1	46
III	0	0	5	5
Total	35	47	6	88

MRI magnetic resonance imaging

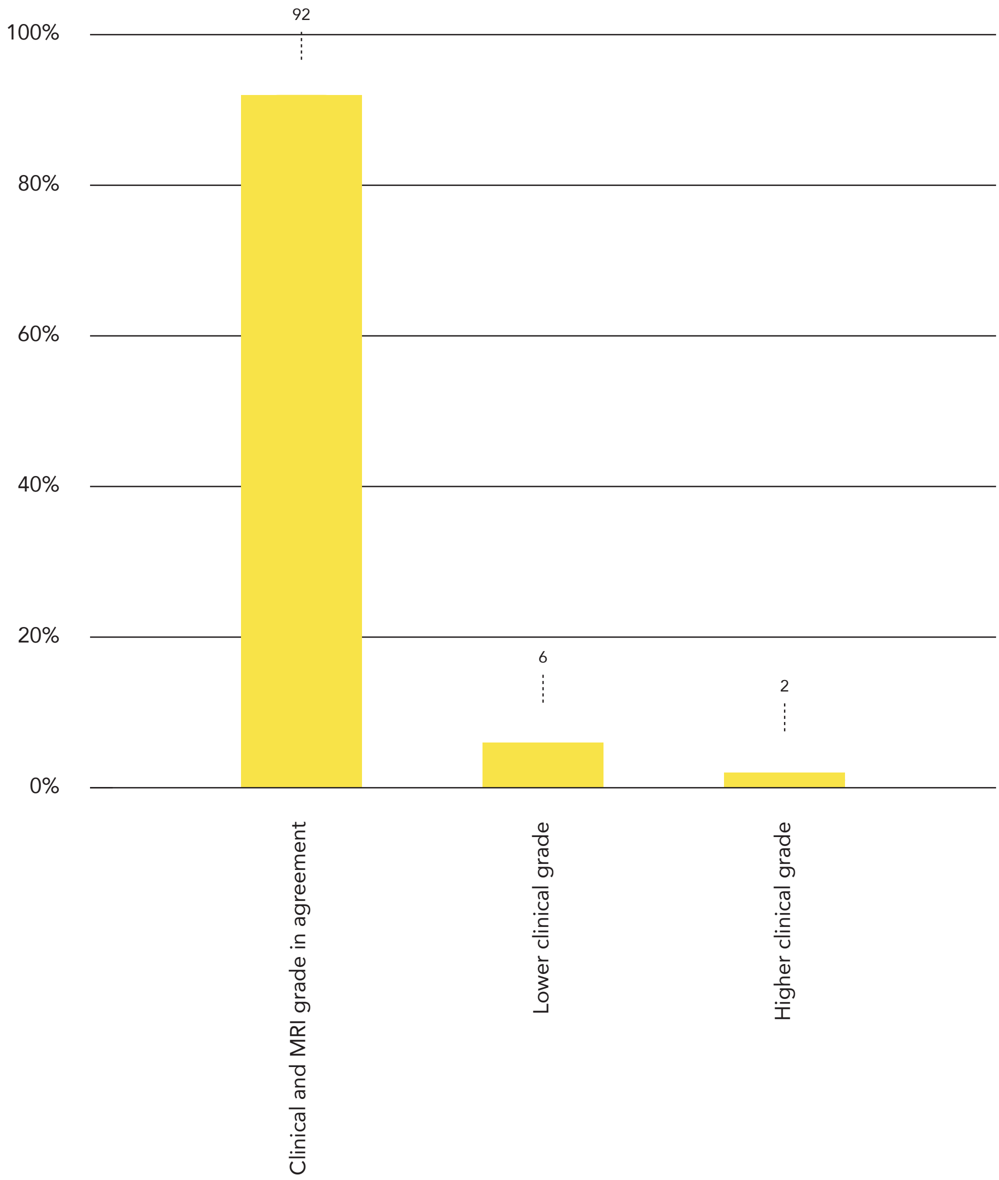

FIGURE 8. The proportion of agreement and non-agreement between the clinical and MRI grading of MCL injuries in professional football

The use of a knee brace increased as the severity of the MCL injury increased, where 25 (53.1%) of all grade II injuries and all grade III injuries (5 of 5 grade III injuries) were treated with a brace. There was a longer lay-off for grade II injuries that were treated with a brace compared with no brace (41.5 ± 13.2 versus 31.5 ± 20.3 days, p=0.01). Among grade I MCL injuries, only five (6.7%) were treated with bracing.

Injection therapy was used in 32 (25.0%) of all MCL injuries; over 60% of these injections were platelet-rich plasma (PRP) injections. A total of 17 players with a grade II MCL injury were treated with PRP injections. There was no difference in the lay-off time regardless if the player received PRP injections or not.

Study III

A total of 101 players who had sustained an ACL injury were matched with 101 controls without a previous ACL injury. There were no significant differences in training exposure (p=0.58), match exposure (p=0.51), or total exposure (p=0.92) between injured players and controls. The odds of sustaining an injury in the 90-day period did not differ between players with an ACL injury and controls (OR, 1.20; 95% CI, 0.66-2.17; p=0.65). The frequency of absence periods due to injury did not differ between the ACL-injured group and controls (OR, 1.14; 95% CI, 0.64-2.01; p=0.77).

TABLE 11. Summary of demographics and findings from Study III

	ACL-injured group (n=101)	**Control group (n=101)**
Mean age ± SD	25 ± 4.1	25 ± 3.9
Defenders (n)	31	31
Midfielders (n)	45	40
Forwards (n)	25	30
Total injuries (n)	42	46
Injury incidence	6.5 injuries per 1,000 h	7.1 injuries per 1,000 h
OR of sustaining an injury in the 90-day period (ACL injured group vs controls)	OR = 1.20, 95% CI 0.66-2.17; P = 0.65	
OR of absence from play due to injury during the 90-day period (ACL-injured vs controls)	OR = 1.14, 95% CI 0.64-2.01; P = 0.77	

ACL anterior cruciate ligament *OR* odds ratio

8 DISCUSSION

DISCUSSION

This thesis provides new knowledge on injury incidences, injury mechanisms, injury severity and treatment alternatives for the four main knee ligament injuries related to men's professional football. This knowledge is important for everyone involved in the game of football, as it can be used to estimate the hazards involved in injury and to take action to prevent injuries. One of the main findings was that MCL injury was the most common knee ligament injury, as it is far more common than LCL, ACL and PCL injuries, showing the medical teams that they need to be prepared for MCL injuries more frequently compared with the other knee ligament injuries. Moreover, the collateral ligament injury rates have decreased significantly during the last two decades. Another important finding was that the majority of MCL, LCL and PCL injuries were sustained in contact-related playing situations, as different from ACL injuries, which mainly occurred due to non-contact mechanisms.

The incidence of knee ligament injuries

The incidence of knee ligament injuries was found to vary between 0.01 and 0.33/1,000 h. Not surprisingly, there was a large difference between specific knee ligament injuries, where an MCL injury was found to be the most common knee ligament injury among male professional football players, while a PCL injury was the most rare. In other words, this means that a men's professional team, typically with 25 players in the squad, can expect approximately two MCL injuries a season, while a PCL injury can only be expected every 17th season (Table 13).

TABLE 13. Number of knee ligament injuries that a team can expect on average

Type of injury	No of injuries per season	Seasonal frequency
MCL injuries	2.0	One every half season
ACL injuries	0.4[114]	One every second season
LCL injuries	0.3	One every third season
PCL injuries	<0.1	One every 17th season

MCL Medial collateral ligament *ACL* Anterior cruciate ligament *LCL* Lateral collateral ligament *PCL* Posterior cruciate ligament

The fact that an MCL injury is the most common knee ligament injury is well known from previous studies of high-level football players reporting that MCL injuries represent a large proportion of all knee ligament injuries. For example, Waldén et al.[107] reported that an MCL injury was also the most common knee ligament sprain in the Swedish men's first league, constituting 54% of all knee ligament injuries. However, data on the incidence of MCL injuries in relation to exposure time in men's professional football are scarce. The results of this thesis can therefore help the medical teams to be prepared for the approximate number of injuries that can be expected each season. This knowledge is important from a general risk management perspective, since the responsible person from the medical team will be able to help the club to ensure the correct resources and competence for what may happen during the season in terms of knee ligament injuries. In terms of the proportion of MCL injuries in relation to the total number of injuries, one interesting observation was that the MCL injuries constituted a larger proportion in Study I over 11 seasons, 2001-2012 (4.3%), than during the subsequent three seasons, 2013-2016 (3.0%), in Study II. The reason for this finding could be a continuous decrease in MCL injury incidence over time, which was already observed in Study I, and this would also be in agreement with an overall decrease in the time trend for ligament injuries in the UEFA ECIS.[36] Interestingly, ankle ligament injuries have also shown a decreasing year-by-year trend[111], but, in contrast, ACL injury incidence has increased slightly in absolute numbers, even if the increase is not statistically significant[113]. Conflicting time trends have also been reported for muscle injuries, where the adductor-related injury incidence has decreased significantly[114], but the hamstring injury incidence has increased significantly over time[39].

In terms of the second most common knee ligament injury, the ACL injury, previous studies of comparable cohorts have reported that the ACL injury incidence ranges between 0.04 and 0.08 injuries per 1,000 h[13, 90, 110]. Moreover, it has been reported that a team can expect approximately 0.4 ACL injuries a season[113].

LCL injuries, which are the third most common knee ligament injury, have been studied on a limited scale in similar cohorts in men's professional football, a finding that was also reported by Ekstrand et al. when studying the most commonly sustained injuries in the UEFA ECIS[40]. The fact that LCL injuries are among the most common injuries and that they have nonetheless been sparsely investigated shows that more knowledge of the epidemiology is needed. Even though LCL injuries only constitute 0.7% of all injuries in the UEFA ECIS cohort, which can be compared with MCL injuries constituting 3.8%[40], further studies are needed to be able to offer the best possible care to the players sustaining LCL injuries. However, PCL injuries have never been specifically investigated in the UEFA ECIS cohort and the findings in this thesis indicate that these injuries are highly uncommon. It is notable that football has, however, been reported to be one of the most common sports causing PCL injuries[93]. A recent study of cruciate ligament injuries in German professional football reported that PCL injuries constituted 2.0% of all injuries, which is higher than what was found in Study IV[66]. The reason for this discrepancy is not known, but the cohort in German professional football was much smaller, which could be one explanation.

Mechanism and timing of injury

As shown in Studies I, II and IV, the dominant injury mechanisms for MCL, LCL and PCL injuries were contact-related playing situations, whereas it is known that non-contact injury mechanisms are most frequent for ACL injuries[112]. Three of four MCL injuries occurred in contact situations, with being tackled by an opponent as the most common injury mechanism (Study II). Consequently, preventive efforts, such as player and referee education, reinforcements of the existing Laws of the Game and the introduction of modern technology including a post-match video review with possible sanctions for the offending player, might be important factors to consider when striving to reduce the rate of these contact-related knee ligament injuries. Interestingly, both MCL and LCL injuries occurred at a higher rate than expected in the last 15 minutes of each half in in Studies I and IV. It is likely that the players are more tired at the end of each half during matches, even though it has also been found that temporary fatigue could affect players for shorter periods throughout the match[79]. Whether fatigue plays a role in this increased rate of MCL and LCL in the last minutes of each half is unknown, but there are a few studies reporting an increase in overall injuries and muscle injuries during the last part of a football match[34, 53], suggesting a possible association with fatigue. A similar timing was, however, not found for PCL injuries in Study IV, which is in line with the finding that ACL injuries in fact appeared to occur to a greater extent within the first 15 minutes of the first half or at an early stage among newly substituted players in the second half[110]. It is possible that the risk is increased due to fatigue, but the true causality is still unknown. Future studies combining measures of intensity and performance related to the timing of injuries are needed to obtain even more knowledge.

Injury severity and lay-off days

The severity of injuries in all the studies included in this thesis is defined as the number of lay-off days according to the consensus statement[49]. In spite of large variations, a basic knowledge of the average number of lay-off days could be used by club medical staff, as an evidence-based forecast of RTP, which is important for decision-making and communication with all the involved parties, such as the player and the coaching staff but sometimes also the media.

Collateral ligament injuries can be regarded as fairly mild injuries with only a few weeks' lay-off in general, compared with cruciate ligament injuries, where the player is sidelined for several months. The median lay-off for an MCL injury was 16 days in Study I and 12 days for an LCL injury in Study IV. It was found that only a quarter of the MCL injuries were slight/minimal injuries (< 7 lay-off days) and around 28% of the LCL injuries were slight/minimal injuries. It is important to consider that these findings might have been an underestimation due to the difficulty involved in differentiating between a low-grade sprain and a contusion to the MCL. It is possible that the mild MCL injuries might have been over-diagnosed and that the injuries reported as mild MCL injuries could instead have been contusions. The remaining moderate to severe (> 7 lay-off days), MCL and LCL injuries, are in fact more relevant to football due to their longer lay-off time. However, in both Studies I and II, the MCL-injured players returned to play within a relatively short period, suggesting that the medical service including rehabilitation at the professional clubs is at a high level and in line with what previous studies have reported after similar injuries[62, 104].

Cruciate ligament injuries are more severe than collateral ligament injuries. The lay-off for players suffering an ACL injury in men's professional football was found to be around six and a half months from the date of the injury in Study I, while PCL injured players have a lay-off of around one month in professional football, according to the data presented in Study IV. Waldén et al.[113] reported that the median lay-off time for male professional players who underwent ACL reconstruction was 6.6 months to training and 7.4 months until the player played his first match. This time to RTP is relatively short taking current recommendations into consideration, i.e. pointing out the importance of not RTP too early, at least not before the nine to 12 months that have recently been recommended[103], because of the high risk of re-injury[82]. A previous study of ACL injuries from the ECIS reported a 4% overall re-rupture rate for a median return to match play of 7.4 months, but the re-rupture rate for the first year was 7%[113]. This raises the concern that an early RTP is associated with a higher risk of re-rupture of the ACL. So, even if a professional football player is more closely supervised by the medical team and has greater access to rehabilitation compared with amateur level, it is important to assess readiness for RTP on an individual basis and to make sure that sufficient time is allocated to rehabilitation before returning to play even at professional level to minimise the risk of re-rupture.

Somewhat surprisingly, we found a median lay-off of one month for a PCL injury, which can be regarded as a short time period for this type of injury. The most plausible explanation is that there is a wide variety when it comes to the way medical teams classify PCL injuries and/or that many grade I sprains not requiring specific bracing were captured. However, by not excluding the somewhat unrealistically low lay-off injuries, it is possible to present a true estimation of the incidence of PCL injuries that, according to the medical teams, occur in professional football. Future studies should include data on treatment in the analysis of lay-off times for both PCL injuries in football to help clinicians in the decision-making process and understand the outcome of different treatment options. It would also be interesting to evaluate the diagnostic modalities for PCL injuries and a sub-study of PCL injuries in the ECIS, similar to Study II in this thesis, would be able to provide important information on this topic.

Diagnostics and imaging

Study II is the only study in the current thesis including prospectively collected data on the diagnostic measures and treatment modalities that were used by football clubs. For MCL injuries, MRI was used to establish the diagnosis in more than two thirds of the injuries. Waldén et al. showed that, for ACL injuries, the frequency of using MRI was even higher, almost 100% of players with ACL injuries had an early MRI and subsequently underwent ACL reconstructive surgery[113]. Importantly, there was almost perfect agreement between the MRI and clinical gradings, which suggests that MRI imaging may not be necessary for future studies of MCL injuries. However, the order in which the clinical and MRI grading of MCL injuries was performed may have varied between teams and clinicians and this may have affected the reported grading of the injuries. It would be more optimal if all clinical grading was reported before MRI grading was determined. At the professional playing level, the economic incitement of not performing an MRI is low, as the cost of an MRI is very small in relation to the turnover at the clubs and it is therefore reasonable to assume that the clubs will continue performing MRI on a large proportion of MCL injuries, despite this novel finding. Although we sought to include MCL injuries as the main diagnosis, MRI also meets another important objective which is to identify or rule out any possible concomitant intra-articular injuries, such as meniscal and cartilage lesions. It is notable that the MRI evaluation in Study II found that 88% of all MCL injuries were isolated without any concomitant meniscal or cartilage injury. The reason for this might be that the majority of injuries were also contact injuries and that a direct trauma to the knee joint might not result in concomitant injuries to the same extent as non-contact injuries with rotational trauma. It is known that rotational trauma may cause more severe injuries, both to other ligaments and to structures such as the menisci and cartilage. The use of MRI is also important in LCL and PCL injuries, to determine the degree of ligament rupture and to identify concomitant injuries.

Grading and bracing of MCL injuries

In Study II, it was shown that, in most cases, grade I MCL injuries were treated without a stabilising knee brace and that all grade III MCL injuries were braced. It appears, however, that team physicians individualised the bracing decision in grade II injuries, where just over half of these injuries received a stabilising knee brace. Interestingly, the use of a knee brace was significantly associated with a longer lay-off period (almost two weeks) compared with not using a brace in players who had sustained a grade II MCL injury. However, it is still not known whether it is the knee brace per se that inhibits the progress of the rehabilitation or whether it is the difference in the treatment culture at the clubs. It is also possible that the club medical staff use a knee brace in the clinically more severe grade II MCL injuries and that they consequently take longer to be sufficiently intact for return to play. Based on the findings relating to MCL injuries in Study II, the use of a brace in grade III injuries is always indicated and it should be used individually for grade II injuries based on a case-by-case evaluation.

9 STRENGTHS AND LIMITATIONS

STRENGTHS AND LIMITATIONS

The main strength of the studies included in this thesis is the general registration process, which followed a standardised method of prospective data collection for a homogeneous population of male professional football players. First, the methodology follows the consensus statement on how to conduct epidemiological studies in football, making it possible to compare the results with those of other studies following the same consensus statements[49, 56]. Second, the prospective design is preferred over a retrospective design because the recall bias risk is removed[49]; it has previously been shown that two-thirds of all injuries were missed using a retrospective design[63]. Third, all exposure data are collected at individual level, which makes it possible to capture more injuries and to establish more precisely the severity of recorded injuries when connected to a specific player rather than studies using a traditional team-based exposure registration[65]. Another strength was the constant supervision of the data, where the study groups went through all the obtained data manually, making sure the data were complete, accurate and coherent with the study methodology before entering the data in the ECIS database.

There are also limitations to this thesis that need to be mentioned. First, the data collection procedures can vary between teams, but, to overcome this and to ensure high quality in the collected data, a detailed study manual was given to the contact persons at all the teams participating in the study. The study manual includes all the definitions and information on how to complete the study forms, including fictive examples and scenarios. Second, all the knee ligament injuries included in the studies are the ones that the medical teams recorded as the primary diagnosis. Consequently, MCL, LCL and PCL injuries that occurred concomitantly with an ACL injury were excluded. It would, for example, be impossible to register the specific lay-off time or treatment alternative for an MCL injury, which is a concomitant injury to an ACL injury where the MCL injury lay-off would then be several months due to the ACL lay-off dominating the RTP decision. It is therefore more reasonable to register the injuries where the specific ligament being studied is the main diagnosis. Third, it is important to consider that the injury mechanism is reported according to what the contact person at each club observes or is informed about. Playing situations occur very rapidly, which can make it difficult to establish the exact injury mechanism. However, the extent to which the medical teams used videoclips to evaluate injury situations when completing the injury form is unknown. Fourth, the order in which the clinical and MRI grading of MCL injuries was performed may have varied between teams and clinicians in Study II. It would have been more optimal if the clinical grading of MCL injuries had been reported s before the MRI grading was determined so that the clinician was not influenced by the MRI grading in the radiological report. The severity grading according to time loss in Studies I and IV is limited, as no mandatory information on clinical or radiographic grading nor whether the injury was partial or complete was requested. As a result, no detailed data on diagnostic evaluations were obtained.

Fifth, there was no information on why a brace was or was not used or which kind of brace was prescribed in Study II. The stabilising brace used for MCL injuries usually has hinges that prevent side-to-side motion and allow full flexion and extension. There are specific functional braces, so-called “sports braces” of different models, that perform a similar function, but allow more aggressive physical activity. We do not know whether these modified versions of MCL stabilising knee braces actually provide full side-to-side external mechanical support and this may affect the outcome in terms of lay-off time. Moreover, we do not know whether the players sustaining a knee ligament injury were playing from the beginning of the game or entered the game at a later stage, which can affect the timing analysis. Moreover, there was a limited number of PCL injuries which may have affected the analysis of timing and made it impossible to analyse time trends.


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FUTURE PERSPECTIVE

This thesis provides epidemiological data on men's professional football. For an increased knowledge of the risk factors and consequences of a knee ligament injury, future studies should optimally use technology measuring individual loads and combine this with individual and team factors for a correlation to injury risk. A better understanding of risk factors is an important step towards reducing the number and severity of knee ligament injuries in men's professional football. Further studies that specifically include detailed data on treatment in order to correlate the lay-off time to different treatment strategies are also needed. Medial collateral ligament, LCL and PCL knee ligament injuries typically occur during matches and, as different from ACL injuries, are associated with a contact injury mechanism. Using video-based analysis in combination with medical information from the contact person at the clubs could provide a more complete description of the injury mechanisms leading to the injury. There is a need to educate the referees on playing situations, which are known to be the cause of contact knee ligament injuries and further studies to measure the injury incidence before and after the education to evaluate a possible reduction in injuries from these interventions are of interest. Medical staff representation on the board of a professional club might be a key factor to help the club understand that the ability to forecast the number of high-quality players each team needs over a season in terms of injury incidence and lay-off time and which skills need to be recruited to the medical team lies with the team physician and team physiotherapist.

CONCLUSIONS

STUDY I

- Eleven consecutive seasons in men's professional football showed that MCL injury is the most common knee ligament injury and the median lay-off from football for MCL injury is 16 days.

- The MCL injury rate decreased by 7% annually during the 11 consecutive seasons.

STUDY II

- Most MCL injuries occurred through a contact mechanism, where being tackled and tackling were the most common playing situations.

- The clinical grading of MCL injuries in elite football corresponded well with MRI grading.

- The grade II MCL injuries that were treated with a brace had a longer lay-off, indicating that routine bracing may not be necessary in milder cases.

STUDY III

- Professional football players do not have a higher incidence of injuries in the three months prior to ACL injury than ACL-healthy controls.

STUDY IV

- Seventeen consecutive seasons in men's professional football showed that LCL injury is the third most common knee ligament injury and the median lay-off from football is 15 days.

- LCL injury was most commonly sustained in contact situations, where being tackled and collision were the most common playing situations.

- The LCL injury rate decreased by 3.5% annually during the 17 consecutive seasons.

- Seventeen consecutive seasons in men's professional football showed that PCL injury was the most uncommon knee ligament injury and the median lay-off from football was 31 days.

- PCL injuries most commonly occurred in contact situations where being kicked and being tackled were the most common playing situations.

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APPENDICES

APPENDIX 1

Appendix 1. Teams from Elite Club Injury Study eligible for inclusion during specific seasons and in individual papers.

	01/02	02/03	03/04	04/05	05/06	06/07	07/08	08/09	09/10	10/11	11/12	12/13	13/14	14/15	15/16	16/17	17/18	Tot seas
Arsenal FC	I, III, IV	I, III, IV	I, III, IV	I, III, IV	I, III, IV	I, III, IV	I, III, IV	I, III, IV	I, III, IV	I, III, IV	I, III, IV	III, IV	II, III, IV	II, IV	II, IV	IV	IV	17
PSV Eindhoven	I, III, IV	I, III, IV	I, III, IV	I, III, IV	I, III, IV	I, III, IV	I, III, IV	I, III, IV	I, III, IV	I, III, IV	I, III, IV	III, IV	II, III, IV	II, IV	II, IV	IV	IV	17
Real Madrid CF	I, III, IV	I, III, IV	I, III, IV	I, III, IV	I, III, IV	I, III, IV	I, III, IV	I, III, IV	I, III, IV	I, III, IV	I, III, IV	III, IV	II, III, IV	II, IV	II, IV	IV	IV	17
FC Barcelona			I, III, IV	I, III, IV	I, III, IV	I, III, IV	I, III, IV	I, III, IV	I, III, IV	I, III, IV	I, III, IV	III, IV	II, III, IV	II, IV	II, IV	IV	IV	15
Manchester United FC	I, III, IV	I, III, IV	I, III, IV	I, III, IV	I, III, IV	I, III, IV	I, III, IV			I, III, IV	I, III, IV	III, IV	II, III, IV	II, IV	II, IV	IV	IV	15
Club Brügge KV			I, III, IV	I, III, IV	I, III, IV	I, III, IV	I, III, IV	I, III, IV	I, III, IV	I, III, IV	I, III, IV	III, IV	II, III, IV	II, IV		IV	IV	14
Juventus FC	I, III, IV		I, III, IV	I, III, IV	I, III, IV			I, III, IV	I, III, IV	I, III, IV	I, III, IV	III, IV	II, III, IV	II, IV	II, IV	IV	IV	14
FC Internazionale	I, III, IV	I, III, IV	I, III, IV	I, III, IV	I, III, IV	I, III, IV	I, III, IV	I, III, IV	I, III, IV	I, III, IV	I, III, IV	III, IV	II, III, IV					13
FC Porto					I, III, IV	I, III, IV	I, III, IV	I, III, IV	I, III, IV	I, III, IV	I, III, IV	III, IV	II, III, IV	II, IV	II, IV	IV	IV	13
SL Benfica					I, III, IV	I, III, IV	I, III, IV	I, III, IV	I, III, IV	I, III, IV	I, III, IV	III, IV	II, III, IV	II, IV	II, IV	IV	IV	13
AC Milan	I, III, IV	I, III, IV	I, III, IV		I, III, IV	I, III, IV			I, III, IV	I, III, IV	I, III, IV	III, IV	II, III, IV	II, IV		IV		12
AFC Ajax	I, III, IV				I, III, IV	I, III, IV	I, III, IV	I, III, IV	I, III, IV	I, III, IV	I, III, IV	III, IV	II, III, IV	II, IV	II, IV			12
Paris Saint-Germain FC	I, III, IV	I, III, IV	I, III, IV	I, III, IV	I, III, IV	I, III, IV						III, IV	II, III, IV	II, IV	II, IV	IV	IV	12
Chelsea FC					I, III, IV	I, III, IV	I, III, IV			I, III, IV	I, III, IV	III, IV	II, III, IV	II, IV	II, IV	IV	IV	11
FC Shakhtar Donetsk							I, III, IV	I, III, IV	I, III, IV	I, III, IV	I, III, IV	III, IV	II, III, IV	II, IV	II, IV	IV	IV	11
BVB Dortmund					I, III, IV				I, III, IV	I, III, IV	I, III, IV	III, IV	II, III, IV	II, IV	II, IV	IV	IV	10
Liverpool FC					I, III, IV	I, III, IV			I, III, IV	I, III, IV	I, III, IV	III, IV	II, III, IV	II, IV		IV		9
RSC Anderlecht						I, III, IV	I, III, IV	I, III, IV			I, III, IV	III, IV	II, III, IV	II, IV		IV	IV	9
Tottenham Hotspur FC										I, III, IV	I, III, IV	III, IV	II, III, IV	II, IV	II, IV	IV	IV	8
FC Bayern München									I, III, IV	I, III, IV	I, III, IV	III, IV	II, III, IV	II, IV			IV	7
Manchester City FC											III, IV	III, IV	II, III, IV	II, IV	II, IV	IV	IV	7
Olympique Lyonnais								I, III, IV	I, III, IV	I, III, IV	I, III, IV				II, IV	IV		6
Southampton FC												III, IV	II, III, IV	II, IV	II, IV	IV	IV	6
Bayer 04 Leverkusen													II, III, IV	II, IV	II, IV	IV	IV	5
Hamburger SV						I, III, IV	I, III, IV	I, III, IV	I, III, IV	I, III, IV								5

APPENDIX 1 (CONTINUED)

Appendix 1 (continued). Teams from Elite Club Injury Study eligible for inclusion during specific seasons and in individual papers.

	01/02	02/03	03/04	04/05	05/06	06/07	07/08	08/09	09/10	10/11	11/12	12/13	13/14	14/15	15/16	16/17	17/18	Tot seas
Celtic FC												III, IV	II, III, IV			IV	IV	4
Club Atlético de Madrid														II, IV	II, IV	IV	IV	4
FC Basel 1893														II, IV	II, IV	IV	IV	4
Galatasaray AS														II, IV	II, IV	IV	IV	4
NK Maribor														II, IV	II, IV	IV	IV	4
Sporting Clube de Portugal														II, IV	II, IV	IV	IV	4
West Bromwich Albion FC											III, IV	III, IV	II, III, IV	II, IV				4
Newcastle United FC						I, III, IV					I, III, IV	III, IV	II, III, IV					4
AS Roma															II, IV	IV	IV	3
Aston Villa FC											III, IV	III, IV	II, III, IV					3
Athletic Club Bilbao														II, IV		IV	IV	3
Blackburn Rovers FC											III, IV	III, IV	II, III, IV					3
FC Zenit														II, IV	II, IV	IV		3
LOSC Lille															II, IV	IV	IV	3
Norwich City FC											III, IV	III, IV	II, III, IV					3
RC Lens	I, III, IV	I, III, IV	I, III, IV															3
SSC Napoli													II, III, IV			IV	IV	3
Sunderland AFC											III, IV	III, IV	II, III, IV					3
Swansea City FC											III, IV	III, IV	II, III, IV					3
FC Köpenhamn													II, III, IV			IV		2
FC Schalke 04													II, III, IV		II, IV			2
Olympique de Marseille													II, III, IV	II, IV				2
Panathinaikos FC												III, IV	II, III, IV					2
PFC CSKA Moskva																IV	IV	2
Queens Park Rangers FC											III, IV	III, IV						2

APPENDIX 1 (CONTINUED)

Appendix 1 (continued). Teams from Elite Club Injury Study eligible for inclusion during specific seasons and in individual papers.

	01/02	02/03	03/04	04/05	05/06	06/07	07/08	08/09	09/10	10/11	11/12	12/13	13/14	14/15	15/16	16/17	17/18	Tot seas
Stade Rennais FC	I, III, IV	I, III, IV																2
ACF Fiorentina									I, III, IV									1
AFC Bournemouth																	IV	1
APOEL FC																	IV	1
AS Monaco																	IV	1
Bolton Wanderers FC											III, IV							1
Cardiff City FC													II, III, IV					1
GNK Dinamo Zagreb																IV		1
Hull City AFC													II, III, IV					1
Leicester City FC																IV		1
Maccabi Tel-Aviv FC															II, IV			1
Olympiacos FC													II, III, IV					1
Rangers FC					I, III, IV													1
Reading FC												III, IV						1
SC Braga												III, IV						1
Valencia CF															II, IV			1
Villarreal CF																	IV	1
Wolverhampton Wanderers FC											III, IV							1

APPENDIX 2.

Appendix 2. Teams eligible for inclusion in study III from Nordic Football Injury Audit.

	2010	2011
AIK		X
BK Häcken	X	X
Djurgårdens IF	X	X
Gefle IF	X	X
Halmstads BK	X	X
Helsingborgs IF	X	X
IF Elfsborg	X	X
IFK Göteborg	X	X
IFK Norrköping		X
Kalmar FF	X	X
Malmö FF	X	X
Trelleborgs FF	X	X
Åtvidabergs FF	X	
Örebro SK	X	X
GAIS	X	X
Mjällby AIF	X	X
Aalesunds FK	X	X
Tromsø IL	X	X
FK Haugesund	X	
Hønefoss BK	X	
IK Start	X	X
Lillestrøm SK	X	X
Molde FK		X
Odd Grenland		X
Rosenborg BK	X	X
Sarpsborg 08		X
SK Brann	X	X
Stabæk IF	X	X
Strømsgodset Drammen	X	X
Viking FK	X	X
Vålerenga IF	X	X
Sogndal IL		X

APPENDIX 3. The baseline form.

Player Details

Name of player	Code	Birth date (yy/mm/dd)	Height (cm)	Weight (kg)	Domin. Leg*	Playing position†	Signature of player/Date

APPENDIX 4. The exposure form.

National team training/match			Matches															Training sessions										
Type of surface																												
Player name	Code	Date																										

APPENDIX 5. The injury form.

Player Details		
Name:	**Team:**	**Code no:**
Date of injury:	**Date of return to full participation:**	(Send injury card, even if player is still in rehabilitation)

Injured Body Part				**Injury side**
☐ Head/face	☐ Shoulder/clavicula	☐ Forearm	☐ Hip/groin	☐ Lower leg/Achilles tendon
☐ Neck/cervical spine	☐ Upper arm	☐ Wrist	☐ Thigh	☐ Ankle
☐ Sternum/upper back	☐ Elbow	☐ Hand/finger/thumb	☐ Knee	☐ Foot/toe
☐ Abdomen				
☐ Low back/pelvis				
Injury side	☐ Right	☐ Left	☐ Bilateral/central	

Type of Injury		
☐ Concussion	☐ Lesion of meniscus/cartilage	☐ Haematoma/contusion/bruise
☐ Fracture	☐ Muscle rupture/strain	☐ Abrasion
☐ Other bone injury	☐ Tendon rupture/tendinosis	☐ Laceration
☐ Dislocation/sublux	☐ Synovitis/effusion	☐ Nerve injury
☐ Sprain/ligament	☐ Overuse unspecified	☐ Dental injury
☐ Other injury (please specify):		

Indicate type of training or match where injury occurred?			
When did the injury occur?	☐ Training	☐ Match (min. of injury)	☐ N/A (overuse injury)
☐ Football training	☐ Football & other training	☐ Friendly match	☐ Europa League match
☐ Other training	☐ Reserve/youth team training	☐ League match	☐ Other Cup match
	☐ National team training	☐ Champions League match	☐ Reserve youth team match
☐ N/a			☐ National team match

Injury mechanism				
Was the injury caused by overuse (gradual onset) **or trauma** (acute onset)?		☐ Overuse	☐ Trauma	☐ N/a
Was the injury caused by contact or collision?		☐ No	☐ Yes, with other player	☐ Yes, with object (specify)
☐ Running/sprinting	☐ Dribbling	☐ Sliding	☐ Heading	☐ Blocked
☐ Twisting/turning	☐ Jumping/landing	☐ Overuse	☐ Tackled by other player	☐ Use of arm/elbow
☐ Shooting	☐ Falling/diving	☐ Hit by ball	☐ Tackling other player	☐ Other acute mechanism
☐ Passing/crossing	☐ Stretching	☐ Collision	☐ Kicked by other player	☐ Unknown mechansim
Injury mechanism (describe in words)				
Did the injury occur outside the pitch perimeter?		☐ Yes	☐ No	☐ Not applicable

Other information			
Was this a re-injury?	☐ No	☐ Yes (give date of return from previous injury)	
Referee's sanction: (acute match injuries only)	☐ No foul	☐ Opponent foul ☐ Own foul	☐ Yellow card ☐ Red card
Examination:	☐ Clinical only ☐ X ray	☐ Ultrasonography ☐ MRI (enclosed MRI form)	☐ Arthroscopy ☐ Other (specify)
Diagnosis: (specify results of examination)			
Best guess as to why the injury occurred: (medical teams opinion)			
Other comments:			

APPENDIX 6. The specific MCL injury form used in Study II.

UEFA CHAMPIONS LEAGUE

MCL Injury card

Name: **Code no:**

Team: **Injury date:**

Pre-injury knee status of the ipsilateral injured knee

- ☐ No previous knee injury
- ☐ Previous knee injury/surgery (specify):

Diagnostic evaluation (several options are possible)

- ☐ Clinical examination only
- ☐ Plain radiographs (specify date):
- ☐ Magnetic resonance imaging (specify date):
- ☐ Ultrasonography (specify date):
- ☐ Arthroscopy (specify date):

Specify findings:

Clinical grading, MCL:

- ☐ I: Pain on palpation/stress test, no or only minimal laxity on clinical examination
- ☐ II: Laxity on examination with semiflexion but not on extension
- ☐ III: Major laxity on examination, total rupture
- ☐ Unknown

MRI grading, MCL:

- ☐ I: Oedema/haemorrhage in or surrounding the ligament, but ligament intact
- ☐ II: Partial ligamentous disruption
- ☐ III: Complete ligamentous disruption
- ☐ Unknown

Location of injury,MCL:

- ☐ Upper third at femoral attachment
- ☐ Lower third at tibial attachment
- ☐ Middle third with +/- injury to the superior and inferior meniscal fascicles

Associated lesion of the ipsilateral injured knee

- ☐ No associated lesion (isolated MCL)
- ☐ Anterior cruciate ligament (ACL)
- ☐ Posterior cruciate ligament (PCL)
- ☐ Medial meniscus (MM)
- ☐ Lateral meniscus (LM)
- ☐ Lateral collateral ligament (LCL)
- ☐ Joint cartilage (JC)
- ☐ Bone marrow lesion (BML)
- ☐ Other associated lesion (specify):

Stabilising knee brace used in treatment?

- ☐ Yes (specify for how long):
- ☐ No

MCL repair or reconstruction

- ☐ Yes, repair (specify date) :
- ☐ Yes, reconstruction (specify date) :
- ☐ No

Graft choice for MCL reconstruction

- ☐ Semitendinosus autograft
- ☐ Achilles tendon allograft
- ☐ Other graft (specify):
- ☐ Other type of surgery (specify):

Injection therapy

☐ PRP ☐Local anesthesia ☐Corticosteroid ☐Other (specify) :

Other comments: