

The effect of a previous anterior cruciate ligament injury on performance in Finnish top-level women football players

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Abstract

Anterior cruciate ligament injuries make a major burden in women's football. Besides requiring a time-consuming rehabilitation period, the rehabilitation of these injuries often leave functional deficiencies to players for further years and are easily recurring. ACL injuries count for a major time loss for all injuries in women's football, but they might also force the women players end their career earlier, not return to play either in the same level, or at all.

The further performance after returning to football has not been widely studied in women's football, and there has been a question whether the history of an ACL injury would impact e.g., on the playing minutes after returning to play in top-level. The aim of the study was to gain further knowledge of performance and further injuries in ACL-rehabilitated players in relation to players without an ACL injury history. The purpose is to clarify the integrity of women's ACL injuries, rehabilitation conventions and the return to play to the top-level football demands. With the data of the UKK Institute and FA Finland, the injury incidence vs. playing minutes was studied. The data of the study were analyzed using statistical analysis methods of SPSS.

The study recognized that the players with an ACL injury history played significantly fever playing minutes in the Finnish National League season 2020 in relation to the players without ACL injury history. There was similarity in the incidence of further injuries in both groups, and in the study the playing minutes in the season weren't related to the incidence of injuries during the same season.

In conclusion, it was suggested that in the rehabilitation of women players to the top-level demands there needs to be a good understanding of the player & rapidly evolved demands of the top-level football in the multidisciplinary medical team that leads the rehabilitation and training of the injured player. In the future, more clear guidelines for rehabilitation of an ACL injured women player in the different stages could be in use for the sports physiotherapy practitioners.

Keywords/tags (subjects)

ACL rehabilitation, women's football, football injuries, return to football, Finnish National League.

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1 Introduction

Football is an ever-increasing sport in the number of active players. It is the most popular sport worldwide and it in times has been studied more than most of the other sports. (Dvorak et al., 2004) Women's football has ran behind men's football in scientific level in most parts of the game, varying from the medicine and science perspective to the social and psychological aspects, but it is known that in elite women's football the physical requirements of the sport have exploded to new levels in recent years (Bradley & Scott., 2019). In elite level sports to this day there lies a lot of equality issues between men and women and the burden of serious knee injuries can as well be considered one of them. The anterior cruciate ligament (ACL) seems to be more prone for injuries in women than in men in almost all playing levels in pivoting sports, including football, as the ACL injury incidence in women depending on the source is 2-8 higher than in men (Lin et al., 2018). ACL injuries usually take months of rehabilitation and therefore they account for a significant percentage of all injury time loss in football teams (Horan et al., 2022).

What highlights the ACL burden is that according to studies, after the primary ACL injury the 68% of women who return to football may experience a new knee injury and may have up to 2-5-times higher risk for any knee injury compared to the uninjured in later years (Fältström et al., 2021). An ACL injury also highly effects on the future sporting career as it may indicate an earlier retirement from football (Niederer et al., 2018; Fältström et al., 2019). In football, most of the players that don't return to play after an ACL injury retire from football for knee related reasons (Sandon et al., 2020). Not returning to the same level or retiring from football could also be a consequence of not being able to return to the pre-injury playing levels or performance. Studies have also urged for the need of prolonging careers of players in women's football as many players are dropping out of football before their potential peak performance age (Barreira, 2016). The prevention of the injuries, especially the ones with the highest burden, and effective rehabilitation of these to performance can be crucial in the road of a single player.

The further development of the ACL prevention & rehabilitation can be seen as a horse race against the time and speed of the development of the modern-day women's elite level football requirements. The physical revolution of the women's game also puts grass roots team environments in small countries such as Finland in the place where shortening duration and effective rehabilitation following severe injuries might have high importance as a means of giving players more healthy training and competing days in player's pursue to e.g., international level. In women's football, the performance after ACL injury has not been studied earlier.

2 Theoretical basis

2.1 Finnish National League 2020

The National League (Kansallinen Liiga) is the highest-level league in women's football in Finland. Inside the league there are 10 teams, and the season consists of two-fold regular season (18 matches), after which the 6 highest-ranked teams play a one-fold (5 games) final series, and the 4 lowest-ranked teams play a two-fold (6 games) final series. The season of this study (2020) was an exceptional season due to the Covid-19 pandemic, and on that year only the regular season was played in the National League. The season of 2020 started later, on 13th June, due to the pan-demic. (Kansallinen liiga, 2022 April 29)

2.2 Physical demands in women's elite football

An adult football match consists of two 45-minute halves which makes a 90-minute match, and usually the end of both halves involve a few minutes extra time. During a 90-minute match the players are required to execute numerous repetitive rapid actions inside the high-demanding endurance context, e.g., sprinting, turning, accelerating, decelerating, kicking, tackling, jumping, and balancing with an involvement of other players and the ball. Along with the good endurance capacity, it is important in football to have strong strength and power abilities to also help perform those previously mentioned actions continuously in a match as well as recover to execute them from week to week. (Stølen et al., 2005)

In the elite level, the physical responses for a player in a football match can highly vary between the teams and positions and are affected by e.g., the tactical perspectives of the teams. The FIFA & UEFA physical reports of women's elite football competitions have shown that the high velocity running demands of game have remarkably risen in recent years in both club and national team competitions. In the two latest women's World Cup competitions, the teams that have ran the least in the higher speeds on average have not been successful in the campaigns which makes the high-speed running a potential performance measure. (Bradley & Scott., 2019; Clubb et al., 2022) In a study that involved a comparison of the Finnish National League demands on the season 2020 it was found that out of the players that played a full 90-minute game the average distance travelled in a game was 10134 meters. An average maximum speed the Finnish National League players reached in the games was 26,6km/h, and the average heart rate during the games was 85,7% from the maximum heart rate. Most of these values were slightly varying for the different playing positions. The Finnish National League differs from the top elite leagues in e.g., lower frequency of high-intensity actions and sprints executed in national league compared to top elite game in all playing positions. (Mäkiniemi, 2021)

2.3 Injuries in women's football

Due to the nature of the game few injury categories rise above others in football. For the professional & semiprofessional women players the studies have shown that the most typical injuries are lower limb ligament (ankle & knee) and muscle (strain & contusion) injuries (Mayhew et al., 2021). The thigh and especially hamstring has been seen to be the most common area of injury in elite level football, and the knee ligament injuries are seen to be the most time-consuming injuries in both sexes (Hägglund et al., 2009). Given the relatively high incidence of thigh muscle injuries and high severity of knee ligament injuries, they both are among the main targets of injury prevention in women's elite football.

It has been mentioned that the time loss for similar injuries shows out to be higher in women players vs. men players (Larruskain et al., 2018). Mayhew et al., (2021) reported that in the women's football studies that have assessed the severity of injury by the length of time-loss from domestic football the moderate time loss (8-28 days) injuries have been seen to be the most common injuries (34%), followed by mild (3-7 days) injuries (33%), severe (>28 days) injuries (18%), minimal (1-3 days) injuries (12%), slight (zero days) injuries (2%) and career ending injuries (0.7%). In the domestic elite-level women's football the total incidence rate lies at 5.7 injuries per 1000 hours of participation, as the match (19.5/1000h) and training (3.2/1000h) incidences are differing. (Mayhew et al., 2021)

Considering which players are potentially more prone to injuries in elite women's football, it has been shown that previous injuries (especially in the same anatomical location), joint hypermobility, and negative life-event stress/anxiety could be few factors that potentially increase the injury risk in elite women players. Positionally, attackers and defenders have been found to be in an increased risk for ACL-injuries compared to midfielders which has been proposed to potentially be related to more aggressive actions and contacts near the goal. These positional risks have also been seen in male football. (Alahmad et al., 2020)

Exponentially increasing running demands and high-speed actions in women's elite football have been suggested to increase the load and injuries in the thigh area. In the analysis of recent women's FIFA World Cup tournaments, it was reported that the high-speed running distances of the teams during the 2019 World Cup in France were 30% higher than in the 2015 World Cup. (Bradley & Scott., 2019)

The increasing number of e.g., thigh muscle injuries despite the increased use of targeted preventive programs, and growing number of artificial grounds as playing surfaces in Finland are factors that make it important to update potential risks and associations of the most common injuries seen in Finnish women's football. In the last decades in men's football, the incidence rate of muscle injuries has not decreased like other categories (Ekstrand et al., 2021). It can be argued that this may be due to the increased number of high-speed actions in the game but potentially also due to the increased capability of players to execute more of the peak speed actions, and whether the same feature occurs for women players. The knee ligament injuries (like ACL-injuries) are usually the most serious & long-term injuries and occur potentially more often in women vs. men in football which puts optimal physical preparation and mitigation of the injury risk in the front line of the women's game development (Bradley & Scott., 2019). A declining overall incidence of injuries in both matches and training in male football in recent decades may be a sign that preventing injuries in men's teams has become highly effective (Ekstrand et al., 2021).

2.4 Anterior cruciate ligament (ACL)

The anterior cruciate ligament (ACL) is a central knee ligament (Figure 1) that among knee tendons and musculature has a functional role in stabilizing anterior tibial translation and internal rotation of the knee. It originates from the medial side of the lateral femoral condyle, and it inserts to the tibial plateau close to the anterior horn of lateral meniscus. It forms two functional bundles, the anteromedial & posterolateral bundle, which are associated with different roles in the stabilization of the knee. In the pivoting sports the ACL injury is a relatively common and time-consuming trauma, and it's often associated with other ligamentous and meniscus injury additions. (Domnick et al., 2016)



Figure 1. Cruciate ligaments of the knee (Mayo Foundation, 2022)

In the case of an ACL injury, there are few possible alternatives for the treatment. The surgical reconstruction of the ligament using either patellar or hamstring (semitendinosus/gracilis) tendon, is still a widely popular method (Cerulli et al., 2013). However, the surgical repair isn't at all the only way to return to pivoting sports, and it has been studied that non-surgical treatment can also lead to similar outcomes in the knee function and participation in athletes (Grindem et al., 2014).

2.5 ACL injuries in women's football

The women athlete's ACL is seen to be more prone for injuries than male athlete's in wide range of playing levels in pivoting sports, with the incidence of ACL injuries in women depending on the

source is 2-8 higher than in men (Lin et al., 2018). In elite women's football, the match play accounts for most of the risk increase, whereas training incidences are similar in men and women (Waldén et al., 2011). In the elite male football leagues, the overall ACL rupture season prevalence has been seen to be 1.32 % (Niederer et al., 2018).

Even though it isn't relatively common for a single player to undergo an ACL-injury, the injury burden (combined injury frequency & severity) for this severe injury is high. In male professional football it has been studied that the two most common severe injuries, an ACL-injury and lateral meniscus injury, together cause 18% of all days out from football from the 31 most common diagnoses (Ekstrand et al., 2020). Conversely, in the Irish study on women's top-level football, the 8 ACL-tears documented over the 2 seasons which accounted for 28% of all time lost in the study. A two-year prospective study reported that knee and ankle ligament injuries, including anterior cruciate ligament tear, resulted in the highest injury burden with almost 50% of knee injuries being severe (resulting in time-loss of >28 days) during 2018 & 2019 seasons. (Horan et al., 2022).

The ACL injuries in elite women's football have been studied to predominantly occur by non-contact & indirect mechanisms, often in some of the three movement patterns: Defensive pressing/tackling, regaining balance after kicking or indirect contacts when being tackled. There is remarkable similarity in the kinematic (Figure 2) ACL-injury patterns in women's football vs. men's football. Accumulated fatigue has not appeared to be a major risk factor in the ACL-injury incidences in women. (Lucarno et al., 2021) In football the ACL injuries have been seen to happen the most often in the early parts of the game (Sandon et al., 2022).



Figure 2. Frequently observed mechanism for non-contact ACL injuries (Della Villa et al., 2020)

Anatomical risk factors that are more often seen in women than men include e.g., the smaller size of the anterior cruciate ligament, increased posterior-inferior tibial slope, smaller femoral notch width and generally increased ligament laxity (Lin et al., 2018). Studies considering more functional sex differences have mentioned increased ACL injury risk as consequence of higher dynamic valgus and quadriceps-to-hamstring-ratio demonstrated during landing in women (Hewett et al., 2005). It has been widely shown in men's football that other previous injuries are a risk factor for a further injury (Hägglund et al., 2006; Bisciotti et al., 2019; Emery et al., 2005; Arnason et al., 2004).

In the young women athletes, it has been studied that an effective and efficient way to prevent these injuries is to combine plyometrics, strength, stabilization, and feed-back driven technique training in young age during preseason and season. As knee injuries early in life can affect in various ways to e.g., knee health and quality of life in long term, the need to prevent these injuries especially in youth is vital. (Myer et al., 2013) Although it's seen that the neuromuscular training is effective for prevention, a higher adherence for that is desirable (Sandon et al., 2022).

2.6 ACL injury prevention in women's football

In a study considering elite women football player's experiences prior to an ACL injury, it was pointed out that the interventions to help decrease women athlete's injury risk could be entered from multiple levels such as athletes, coaching practices, interpersonal communication and relationships, interactions with medical staff, and team climate & culture (Ivarsson et al., 2019).

It is reviewed that male football players might benefit more from prevention programs like FIFA11 and FIFA11+ than women, but one issue with this is that women players have not been as widely represented in the studies of this topic (AI Attar et al., 2016). It is important in the future to also include women players more in the study of effective/ineffective prevention strategies for an ACL injury in general as the burden of this injury is high in women's elite football. In the FIFA & UEFA physical reports of women's elite competitions it has been shown that e.g., the running demands of the game have remarkably risen in a short period of time (Bradley & Scott., 2019; Clubb et al., 2022). This may also put the perspective of injury prevention to a different level as the team staff needs to prepare the players to tolerate a growing physical output on the pitch. In the light of growing physical demands in women's elite football, there is a need to be cautious if the prevention addressing studies from years back can be applicable to a modern game.

Tiredness, stress, burnout and overtraining signs with insufficient sleep and bad performance climate could be potential ACL injury risk factors in women players/athletes (Elliot et al., 2010). Ivarsson et al (2019) resembled that sometimes in top-level sports environments the sociocultural standards where players are pushed to compete through pain and injury exist and this might also increase the injury risk.

The ACL injuries in elite women's football have been studied to predominantly occur by non-contact & indirect mechanisms, often in situations of defensive pressing/tackling, balancing after kicking and indirect contacts when being tackled (Lucarno et al., 2021). It can be discussed if women elite football players would benefit from being progressively introduced to exercises that recreate these mentioned situations for a possibility to build recognition and solutions for similar situations in game play in prevention and rehabilitation of an ACL-injury.

2.7 ACL rehabilitation in women's football

It is arguably not possible to prevent all ACL injuries. In the case of an ACL tear it is understood that a high-quality, early started preoperative rehabilitation can reduce chances to develop knee related functional issues in the future for players following an ACL injury. For example, full knee ROM before the surgery may prevent postoperative arthrofibrosis and a 20% preoperative quadriceps strength deficit may predict a quadriceps strength deficit for up to 2 years after the surgery (van Melick et al., 2016). Appropriate quadriceps strength can be highlighted also for its potential possibility to reduce risk to future knee osteoarthritis to some extent (Øiestad et al., 2022). A higher pre-injury performance and neuromuscular capacity may accelerate the rehabilitation process (Niederer et al., 2018).

It is important to also note that a surgical treatment in the ACL tear is not the only way for patients to return to pivoting sport activities, as favorable outcomes can as well be achieved through non-operative rehabilitation. Further study is required to help decision-making in which patients are possibly the best candidates for operative -, and non-operative decisions. (Wellsandt et al., 2018; van Yperen et al., 2018)

It has been highlighted that a physiotherapist should be leading the decision-making in rehabilitation, but a good communication between the surgeon, physiotherapist and patient is also of great importance (van Melick et al., 2016). Rehabilitation after the ACL reconstruction is recommended to continue for 9-12 months, but the orientation should still be rather goal-, than time-based with progressive neuromuscular & functional goals and criteria. Open and closed kinetic chain knee exercises are recommended, and towards the late phase of the rehabilitation, more implicit motor learning strategies should be used to help the athlete learn produce firm solutions under stressing & fatiguing conditions they face in sports. (van Melick et al., 2016)

As well as evaluating quantity and quality of the movement, the importance of evaluating psychological changes (e.g., via questionnaires) during this exceptionally long rehabilitation is valid to highlight. Athletes that express higher psychological readiness for sport and knee self-efficacy during early rehab (3 months) have shown to demonstrate better functional and neuromuscular outcomes later (6 months) after ACL reconstruction. (Erickson et al., 2022) Three core supportive factors have been identified in helping women's professional players cope with a first time ACL-injury during the rehabilitation: an ability to set reasonable goals, rich & constructive communication and interaction with player's significant others and strong belief in efficacy of one's own actions (Johnson et al., 2016).

It is also vital to understand possible deficits that an ACL injury may leave on the lower limb. Grindem et al (2014) studied that, not dependent on surgical or non-surgical treatment, 20-30% of patients may experience deficits in flexor/extensor strength, lower than normal reported knee function or a re-injury in further years.

2.7.1 Return to football after the ACL injury

Top-level football requires exceptional physical qualities and the return to play after an ACL injury should be planned gradually and be guided by functional criteria. The inevitable problem with this approach has been a lack of valid functional criteria in the rehabilitation, not to mention criteria specific to a football.

Nowadays it is known that the delay in return to sports activity may be a reasonable way to reduce re-injuries. Bodkin et al (2021) showed that from 8 months after ACL reconstruction every month of delaying return to activity decreased the risk of re-injury to either the operated or the contralateral leg by 28%. Biological experiments have shown that ACL graft growth, including proliferation, remodelling, revascularization and ligamentization of the graft properties, also takes a minimum of 12 months (Janssen & Scheffler., 2014). In the UEFA follow-up of 116 male professional teams during 2001-2017 the median time of absence for an ACL injury (183 injuries) was 205 days, which equals roughly under 7 months. (Ekstrand et al., 2020)

But how do you know when the player is ready to return to football training and competition? Several functional symmetry tests, like horizontal and vertical hop, have become established in helping the decision-making process and assessing progression of the rehabilitation. The practitioner needs to understand functional requirements important for sport-specific return to play in choosing the right tests as it is studied that different hop tests put notable different biomechanical demands on the lower limb. Horizontal jumps can highlight more hip and ankle joint rather than knee and may not therefore be the best in use of functional knee assessment alone. (Kotsifaki et al., 2021) Functional hop symmetry, preferred to use as a battery of tests rather than a single test, should be only one part of a comprehensive return to play decision making process (Ebert et al., 2021). According to the consensus statement of RTS after an ACL injury, a time-based decision making should be replaced by multidisciplinary criteria-based return to sport, though the ideal RTS battery still requires more research (Meredith et al., 2020).

Other tests that are commonly included are e.g., strength progression & symmetry assessments for knee musculature, and psychological readiness assessments, like questionnaires of readiness. Injury–Psychological Readiness to Return to Sport (I-PRRS) scale and quadriceps strength symmetry in rehabilitation have in fact been studied to be associated in women athletes that have experienced a noncontact ACL injury. (Della Villa et al., 2021)

The return to play after an ACL injury, in a physically demanding pivoting contact sport such as football, should be carried out progressively. In the lack of agreed & acknowledged return to play – protocols it could be feasible to use a training framework like 'control-chaos continuum' (Figure 3), in which progressive sport-specific skills, abilities and loads are introduced step by step starting from more controlled sport actions and ending up to more chaotic tasks and competition (Taberner et al., 2019).

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Figure 3. An idea for return to play: Control-Chaos Continuum (Taberner et al., 2019)

The UEFA Women's Champions League 2019-2021 physical data shows that the players in elite women's teams make more peak efforts i.e., run more in higher speed & total distance per minute, in the start of both first and second half of the matches and towards the possibly decisive moments in the end of the game (Clubb et al., 2022). It would be arguably important to predispose players that are returning to play to a sufficient production of higher peak outputs also in a fa-tigued states before the return to high-level competition.

2.8 Performance and game exposure after an ACL injury

As introduced earlier, ACL rehabilitation inevitably requires a long pause from competition and the effects of the injury, possible operative treatment, and the change in the football load on body and performance are worthwhile discussing. Recovery after an ACL injury has been studied to result in an average of 205 to 215 days missed in full training participation in male professional football (Ekstrand et al., 2020; Forsythe et al., 2021). Even though the return to play level after an ACL

injury in (male) professional football is high, Niederer and colleagues (2018) found out that only about 60% return to the same league level as before the injury (Niederer et al., 2018). The level of performance in further years among women players has not yet been studied.

Forsythe et al (2021) observed that after an ACL rupture the player performance was reduced for 2 seasons after an injury as the ACL injured players played fewer minutes (per season & game) and scored less goals until the third and fourth post-injury season compared to their matched cohorts. In the National Football League (NFL, American football) the players that returned to play after an ACL injury started fewer games and tackled less after a season of their surgery (Read et al., 2017). These results are as well taken from elite male athlete population, as the similar factors have not yet widely been studied in women's population.

The impact of ACL injury process on return to play and further performance and playing minutes remains poorly studied to this day especially for women's elite football players. It has been stated in a previous study that in male professional football players the playing time and performance might be affected for up to 2 seasons after their ACL injury, and even further declined performance has been reported for the attacking players who might also return to play later after an ACL injury than the players in more defensive positions (Forsythe et al., 2021; Niederer et al., 2018). Attacking players, along with wide midfielders, cover the longest distances in the high-speed zones in elite football, as it was seen in FIFA 2019 Women's World Cup in France (Bradley & Scott., 2019). It has been studied that in the Finnish National League the players are able to reach similar peak speeds as the players in women's top leagues like NWSL and Danish league but fall behind in the number of high intensity runs (Mäkiniemi., 2021).

2.9 Career and re-injuries after ACL injury

An ACL injury can have a significant effect on the further sport career. According to previous studies, an ACL tear may indicate an earlier retirement from football for both men and women football players which could be connected to not returning to pre-injury playing levels or a decrease in performance. The ACL-injury is already known to have a high re-injury rate especially emphasized in women's football (Niederer et al., 2018; Fältström et al., 2021; Fältström et al., 2019). Similarly, in American football top level (NFL) the players who return to play after an ACL reconstruction retire from sport earlier (Read et al., 2017). A study from women's football reported that after the primary ACL injury the 68% of players who returned to play experienced a new knee injury and had 2to 5-times higher risk for any knee injury compared to their controls in a 5-10 year follow up (Fältström et al., 2021). Importantly, most of the players that don't return to football after an ACL injury retire from football for knee related reasons (Sandon et al., 2020).

It is understood that in football, a previous injury is a risk factor for a further injury (Bisciotti et al., 2019: Emery et al., 2005: Hägglund et al., 2006). It is studied that a previous knee injury could also have an association with further lower leg and foot injuries in women's elite football (Nilstad et al., 2014). Verrall and colleagues (2001) suggested that after a serious injury to the knee, the biomechanical properties of the lower limbs may change, thereby increasing susceptibility to muscular injuries (Verrall et al., 2001). A high fear of reinjury after the index ACL injury has been suggested to be related to a subsequent ACL injury in both the ACL-graft and contralateral ACL. (Tagesson & Kvist., 2016) Young adults (26±8 years old) that have undergone an ACL reconstruction, the hamstring (biceps femoris & semitendinosus) muscles in the operated knee are also suggested to experience an increase in electromechanical delay (a time between the start of muscular activation and the start of an acceleration in a movement) in events of unexpectedly perturbed actions up to two years post-surgery which could potentially affect the stability of the knee in quick actions. (Ristanis et al., 2009)

It's been seen that the number of total further injuries (other than ACL-reinjuries as well) within 5 years post-ACLR did not differ between ACL injured and control groups in male elite football leagues (Niederer et al., 2018), but this might be connected to the fact that during the relatively long rehabilitation period of an ACL injury the injured player is not as much exposed to match play or team training, and therefore injuries, either.

3 Purpose

The purpose of this master's thesis study was to find out if the women players that have sustained an ACL injury in their career, playing in the Finnish National League, perform differently to the players that have not sustained an ACL injury. An effect of the usually long process of the ACL injury to the playing careers and further performance has not been widely studied in the field of elite football, not to mention women's football. In the moment of writing this study, there are no other studies in women's top-level football that assess the ACL injury recovery by the values of performance further in the career. Besides of the assessment of further playing minutes, the potential risk of further in-season injuries was assessed in the ACL injury history group in comparation to the players that have not experienced an ACL injury.

The main research question in this study was:

1. Is an ACL injury history related to a decrease in playing time in women's top level football players further in the career?

Alternative hypothesis: Players with an ACL injury history played less in the further seasons than the players without the ACL injury history. (H1: μ 1 > μ 2)

Null hypothesis: ACL injury history does not have an influence on the playing minutes in further seasons. (H0: $\mu 1 \le \mu 2$)

An additional question regarding the player's ACL injury history was:

2. Are top level women football players with an ACL injury history in a higher risk to more MSK injuries further in their career?

Alternative hypothesis: An ACL injury history is associated with higher occurrence of MSK injuries further in the career. (H1: μ 1 > μ 2)

Null hypothesis: ACL injury history is not associated with higher occurrence of MSK injuries further in the career. (H0: $\mu 1 \le \mu 2$)

This research question was approached through two different outcomes divided by whether the injuries sustained resulted in an absence from the participation or not.

The other additional research question was formed to determine if musculoskeletal injuries during the season are automatically connected to the loss of playing time in the same season. By analyzing the in-season injury data of all teams in the National League the intention was to find out if the injury incidence relates to the amount of playing minutes. The assessment of this research question could be led to further study & discussion of whether the injured players get the adequate recovery for their injury and, on the other hand, if the universal MSK injury incidence predicts the acute performance values in any way. This research question was not dependent on the players ACL injury history.

The other additional research question was:

3. Do musculoskeletal injuries during the League season affect to players playing time in the season?

Alternative hypothesis: Musculoskeletal injuries during the season have an influence on the players playing minutes in the same season (H1: μ 1 > μ 2)

Null hypothesis: Musculoskeletal injuries during the season do not have an influence on the playing minutes in the same season (H0: $\mu 1 \le \mu 2$)

4 Material & Methods

4.1 The initial data collection

This master's thesis study was made in collaboration with a data collected by Tampere Research Center of Sports Medicine, UKK-Institute (Tampere, Finland). The player injury and background data was a part of a larger football injury study produced by the UKK-Institute and the Tampere Sports Medicine Center on Finnish elite men and women football players which was conducted to investigate the incidence of injuries and illnesses in the top leagues. The initial study has been conducted in the women's National League from the season 2020 until the season that is ongoing (2022) during the writing of this thesis, and it also includes several older junior-level teams in the latter two seasons. In the Finnish men's National League, the initial study was conducted for the 2019 season only.

4.2 Data sharing agreement

A written agreement for the usage of the numeric data of UKK-Institute was made between the student and the UKK-Institute. In the agreement it was mentioned that the data will be conceded in an unidentified form and used for the good scientific purposes of this master's thesis only. The anonymity and privacy of the participants in the study was agreed to be protected at all stages during the use of the data and interpretation of the results. The data was agreed not to be copied or conceded to third parties and deleted from the secured storage devices of the student until the end of 2022. The data of the initial study and the list of the participating players (for the collection of the match minutes) was delivered from the UKK-institute to the student in a secured email and stored in the student's personal two-phase identification always secured cloud service during the project before the disposal of the data in the end of this master's thesis process. The study had an ethical approval from the Ethics Committee of Pirkanmaa Hospital District, Tampere, Finland.

4.3 Study design

The study was a one-year cohort follow-up study. Methods in the study were chosen according to international consensus agreements for injury research in football (Fuller et al., 2006) and elite athlete injury monitoring (Clarsen et al., 2020).

4.4 Player recruitment

All 10 teams playing in top-league of women's football in Finland, National League 2020, were invited to the study and an agreement for participation was reached from all teams. Players were informed of the initiation of the study. A parent / guardian of under 18 years old participants were informed in addition. Every player from a participating team was eligible to join the study. A written informed consent from each player was claimed as an agreement to participate. Players that had sustained a severe injury (>28 days off) other than ACL injury under 12 months before the start of the league season 2020 were excluded from the study to help make sure that also the control group was healthy in the start of the playing minute analysis.

4.5 Data collection

Teams in the National League start their pre-season training in November-January and the league season was due to start 27th March in 2020. Due to COVID-19 pandemic the season start was delayed until June 13th and the final round was played on November 8th. During the spring and begin of the summer 2020 the UKK-institute (Tampere, Finland) collected the background data from the attending players via Webropol survey-app and it included information of basic individual parameters (e.g., age, weight, height, illnesses, experience in football) and daily life parameters (e.g., sleeping/training habits) as well as injury history (e.g., details of ACL-injury history & injuries of previous year). The questions in the background questionnaire were mainly composed by the measures that were studied in the injury predicting factor study by Pasanen et al (2015).

The injury data was collected weekly from players also via AthleteMonitoring (AthleteMonitoring, Fitstats Inc., New Brunswick, Canada) and it included an updated version of Oslo Sports Trauma Research Center questionnaire on Health Problems (OSTRC-H2) (Clarsen et al., 2020). If the player reported an injury, there was detailed questions for the body part affected, type of onset (acute injury / overuse injury), and if the injury occurred during a match or training. For the severe injuries, the research assistant approached the players via phone to have the detail of the injury type and whether the injury could be detailed as a contact- or non-contact injury (Table 1). In one attending team the majority of players joined the follow-up data later, in the week 34, which will possibly affect to the reality of occurred injuries in the overall statistics. In two participating teams the weekly injury data was collected via other method than AthleteMonitoring-app, and these teams were not included in the research questions that assessed the weekly injury data in this the-sis.

If the player reported an acute or overuse injury, they had to answer few additional questions (Table 1) that are additional to the OSTRC-H2. An automatic reminder was sent to the players if they had not filled up the weekly questionnaire. In this study, only injuries are included in the data. The reported illnesses are excluded from this data.

Table 1. Injuries: Extra questions clarified by the research assistant (added to original OSTRC-H2)



If the player reported the same injury or again in the further weeks, there was a modified question after the first four questions of OSTRC-H2:"Have you reported this health problem before via this monitoring system?". If the player answered that they had reported the injury before she could see the list of her earlier reported injuries & illnesses and after choosing the correct injury, she would continue answering from the question 15 of the OSTRC-H2. This way the system and the research assistant were able to collect the information of the injuries that extended for further weeks. As single injury could give differing details between the first 4 questions of OSTRC-H2 in different weeks, it was not possible to classify injuries by their effect on detailed participation, performance, training modification or symptoms.

Finnish players filled the questionnaire in Finnish and foreign, non-Finnish speaking players in English. The Finnish questionnaire was a translation of the OSTRC-H2 questionnaire. A reminder was sent three days later if the player had not answered the questionnaire. The research assistant weekly compiled a report from the players that had not filled the questionnaire from the last week and sent it to the named member of team medical staff of every participating team as a double reminder.

Yet in the National League it is not a default value that a physiotherapist is regularly available in a team. If there were uncertainties in the reported injuries the researchers (UKK-Institute, Tampere, Finland) clarified the reports by calling straight to the players for specified questions. Players could give their coaches and medical staff a permission to their weekly injury reports and in some teams, it was possible to clarify the injury reports via questions to team physios. Injury reports based on registration by medical staff only has been found to underestimate the burden of the injury by 50% in women's elite football (Nilstad et al., 2014). This may have added variability to the accuracy of the injury reports to some extent.

4.6 Players with an ACL injury history

In the background questionnaire it was asked whether the player had sustained one or more anterior cruciate ligament injuries (ACL) in their whole career. There were specified questions for the dates, surgeries (operated/non-operated), places and situations of incidence and contact/noncontact natures for the reported ACL-injuries. Players could report the details of maximum of 2 ACL injuries. The ACL relevant questions of the background questionnaire can be found in Appendix 2.

4.7 Individual match exposure

For each player in the data the individual match minutes were manually collected from the FA Finland web database (FA Finland, 2022) where all the official match transcripts are documented, and the individual combined minutes from all official competitions can be counted.

In this study the analysis started from the league opening day (13th of June), and all the official league match minutes were collected until the final day (8th of November) of the league season.

From this period all the other official match minutes were also collected for single players, and this included e.g.: semi-finals (4 teams) and final (2 teams) of the Finnish Cup, 1st & 2nd division -, junior-, and national team level games. Games played before the start of the league season, during winter-spring 2020, were automatically excluded from the analysis. Training match minutes of 2020 were not possible to count in the study, as training match data is not collected in the FA Finland match database.

To minimize the possible effect of any severe injury in the near history to recorded playing minutes, the players who had reported severe injuries (>28 days out from participation) in < 12 months before the league season start on 13th June 2020 were excluded from the analysis. This also included the players that had sustained an ACL injury under 12 months before the start of the league season 2020.

4.8 Injury definition in reports

Total days off from participation were counted from the start of the self-reporting day to the last day of the self-reporting day for each injury. The severity of the injury in the study was defined as the number of days missed from full participation in club training & matches as it has been guided in the Fuller et al (2006) consensus statement of data collection for football injuries: slight (0 day), minimal (1–3 days), mild (4 to 7 days), moderate (8 to 28 days), severe (over 28 days) and career-ending injury (an injury causing the player to stop football playing totally or forcing player to play at a lower level). In the first part of the questions from the modified OSTRC-H2 (Appendix 1) the players also reported the level of participation & pain, training/competition modifications and effect on performance on 4-scale alternatives for every injury they reported. As these levels often varied weekly for the same injury, it was decided with the UKK Institute that they would not be counted and used in analysis of injuries in this master's thesis.

Players and medical staff reported the acute and overuse injuries in the follow-up by different categories. Injury location was chosen from categories based on different body parts. In this section a more specified body part than e.g., "knee" or "thigh" including all components understood to include in these was not asked. Later in the questionnaire player could report extra comments or the injury diagnosis by doctor. Players and the medical staff could also comment their diagnosis of the injury in the comments, and the injury type in the data was a result of the player answers and additions of the medical team and doctors. If the diagnosis was missing or unclear after this, it was clarified by research assistant calling straight to the player.

Two teams reported their 2020 season injuries via different method and all the players of these teams were excluded from the analysis of days off for injuries in this master's thesis study.

5 Statistics

SPSS Statistics 28.0.0.0 (IBM Corp, Armonk, NY) was used to conduct the statistical analysis in the study. The baseline descriptive statistics were reported using mean and standard deviation. Baseline means for age, height, weight, BMI, football starting age & years spent in top league football were reported with standard deviations, and the significance of the group differences in these baselines were shown as p-values of the independent samples t-test where the alpha was set at 0.05.

An independent samples t-test was also used for the comparison of the groups (ACL-group & control-group) in both 2020 league season match minutes and follow-up mean absence from full participation in the season. The distribution of the musculoskeletal injuries during the season as well as musculoskeletal injuries that led to time loss from participation during the season in two groups (ACL-group & control-group) were analyzed with Pearson's chi square. The odds ratio was used to determine the expectation for further injury risk in the groups based on the reported injuries in the season. The independent samples t-test was also used to assess the difference in the season playing minutes in the groups divided by the incidence of season injuries in the additional research question.

The further injury characteristics were combined from the weekly answers from players, phonecall revisions of unclear answers and in some teams, the clarification of injury details from the staff. Incidence of ACL-injuries in career were collected from the background questionnaires of players and the 2020 league season playing minutes were collected after the season 2020 in January 2022 individually for each player from the FA Finland database.

6 Results

6.1 Player characteristics

The assessment of the three different data sets and research questions was executed after the progression in included and excluded participants based on the used data. Figure 4 shows the progression from the primary player data to the data that was used in the different research questions with recruitment (inclusion and exclusion) of the subjects in the study.



Figure 4. Flow chart of the steps of data combining

The characteristics of two groups were viewed before the statistical analysis. The average age of the participating players was 21.5 years so we can consider the women's top football league in Finland to be composed widely of young players. Players in the ACL group were on average older and had spent longer in the top league than the uninjured. The ACL group started their football career on average earlier than the control group. It is easy to understand that a player that has spent more years playing football has also had a higher exposure for possible injuries, including an ACL injury. This was not argued to be related to a defining difference in the characteristics of the groups. The difference in the sizes of the groups is evident and for that reason it is possible that the ACL group is not as representative of the population as the group without an ACL injury history. The p-values of the independent samples T-tests of all the baseline characteristic group differences can be seen in the Table 2.

	Total sample	ACL injury - group	No ACL injury - group	Between group comparison (p- value)
Ν	150	26	124	
Age (years)	21.5 (3.5)	22.5 (3.6)	21.3 (3.5)	.110
Height (cm)	167.8 (6.2)	166.6 (4.7)	168.0 (6.4)	.283
Weight (kg)	64.3 (10.2)	63.0 (6.0)	64.6 (10.9)	.452
BMI	22.8 (3.2)	22.7 (1.7)	22.8 (3.4)	.796
Age of starting football	7.6 (2.3)	6.8 (1.7)	7.8 (2.4)	.062
Seasons played in adult top-level	4.1 (3.3)	4.9 (3.7)	4.0 (3.3)	.201

Table 2. Comparison of groups for National League 2020 playing minutes

6.2 ACL injuries in the National League 2020

From the background questionnaire data, it was found that during the Kansallinen Liiga season 2020, 38 players out of 192 players participating in the data collection reported a history of ACL tear during their career. Out of the occurred ACL tears, 20 were reported in the left knee, 13 in the right knee. 5 players reported a history of ACL tears in both knees. A total number of 8 players out of 38 reported they had suffered an ACL injury at least twice during career meaning that in the National League player background data 2020 there was a total of 46 ACL injury cases in the reported

injury history. In 31 of the 46 (67%) reported ACL injury cases the event of occurrence was reported to be a match. 14 injuries were reported to have occurred during the football training, and in one case the event of occurrence was reported to be "unknown/developed gradually".

Of the 46 ACL injuries reported in the background data, only 8 cases were reported to include a straight contact to the knee in the moment of injury with 2 cases not sure if there was contact or not. This means that at least 78% (36) of the ACL injuries that had occurred the among the players attending to the National League 2020 season had been non-contact ACL injuries.

4 out of 38 players with an ACL injury history reported that their injury had been treated non-operatively meaning that 10,5% of the women players, with an ACL injury history, competing in the National League in the season 2020, had been treated without surgical treatment with their ACL injury. All four ACL tears that were treated non-operatively had occurred in team training and were player's first ACL injuries. In the players of this data there were no non-surgical ACL treatments reported before 2018 but since the start of the 2018 the percentage of non-surgical treatments in National League players has been 22% for all the occurred ACL tears in the players that were still playing in 2020.

6.3 ACL injury history vs. playing minutes 2020

192 players had fulfilled the background data and were eligible for inclusion to ACL injury history and playing minutes 2020 analysis. 7 players in the data had sustained an ACL injury in less than 12 months before the start (13th of June) of the 2020 National League season and were excluded from the analysis of the 2020 playing minutes for possibly incomplete ACL rehabilitation period. Also, 35 players had sustained a severe injury (>28 days off) other than ACL injury under 12 months before the start of the league season 2020 were excluded from the study to help make sure that also the control group was healthy in the start of the playing minute analysis. Both, the background, and the weekly injury questionnaire data source from the pre-season 2020 time were used to identify the players with this exclusion criteria. The final number of players in 2020 playing minutes comparison was 150 (ACL=26 vs. control=124).

6.3.1 Comparison of the playing minutes in the league

An independent samples t-test was conducted to compare match minutes in National League 2020 season for players with (ACL-group, n=26) and without (control group, n=124) ACL injury history. A statistical difference was found in the match minutes for ACL-group (M=739.38; SD=483.48) and control group (M=994.15; SD=557.90) conditions; t(148)=-2.163, p = .032. The mean difference in the groups was 254.8 minutes with 95% CI [22.0, 487.5].

The control group without an ACL injury history played on average 255 minutes more in the season 2020 than the group with an ACL injury history (Figure 5), and the result can be reported to be statistically significant when the $p \le .05$. This difference is equal to approximately 2,8 games less per season for the players with an ACL injury history.



Figure 5. ACL-history vs playing minutes

6.4 Weekly injury surveillance

In the 1st week following the start of the season 2020 (week 25) the average response rate in 8 teams included in the follow-up was 90%. In the last week (week 45) of the season the average answer percentage was 84%. The women had a lot higher percentage than what was seen in the 2020 prospective study for the Finnish first league male teams where the response rate during the start of the study was 73% and during the end of the study 26% (Kurittu et al., 2021).

The players from the team in which majority of the players joined later still reported their past injuries of 12 months before the season, as well as their career ACL injury history, in the background information and the late join-in doesn't affect that much on the season primary research question. Two teams that reported their injuries via other method than the AthleteMonitoring-app are not included in this part of the master's thesis.

6.4.1 Injuries of the National League 2020 season

For the analysis of season 2020 absence for injuries, 36 players of 2 teams were excluded as in these two teams the players & the medical staff reported their injuries to UKK institute via other method than the AthleteMonitoring – system used by the rest of the teams. Also, the same exclusions for the missing background data and existence of severe injuries (>28 days) in under 12 months before the start of the season 2020 were applied as in the playing minute analysis. The final number of players included in injuries & absence comparison was 114. After the exclusions the number of players in the ACL-group was 17 and in the control group the number decreased to 97. At this point the players from the other remaining teams would have also been excluded if there were any players that had fulfilled the background data but not the weekly follow-up question-naire on injuries.

On the follow-up from 13th June 2020 until the end of the season (8th November) a total of 140 injuries were reported for 114 players included in the follow-up (ACL=18, control=122). These 140 injuries were distributed to 80 players in the data. 13 (76%) out of 17 players with ACL injury history and 67 (69%) out of 97 players without ACL injury history suffered an injury during the league season.

The median absence time for all injuries was 2 days (range 0-67 days). For the players with ACL injury history that reported injuries, the median absence time for all injuries (n=18) was 4 days (range 0-39 days), as for the players without the ACL injury history the median absence time for all injuries (n=122) was 2 days (range 0-67 days). 50 injuries were reported as muscle-/tendon related injuries and 39 as joint related injuries. 34 of the injuries occurred in an official match, 44 in football training and in 46 cases the player reported the injury to have developed through overuse in time. From the non-overuse injuries, 28 cases occurred in either a collision or tackle by another player. 11 injuries occurred during a sprint or an acceleration, and 7 were reported to occur in a jump or landing. 12 injuries came from a contact with an object (posts, standings, etc.).

From the three highest categories, 35 thigh-based injuries, 26 knee-based injuries and 19 anklebased injuries were reported. Most (45 cases) injuries resulted in an absence of 1-3 days and in 35 cases there was no absence from full participation needed at all. 11 injuries resulted in over 28 days out from full participation.

6.5 Absence for musculoskeletal injuries in National League 2020

In the first analysis of the injury questionnaires the quantity of the injury days during the season was measured in regards of the groups with all the participating players included. All the players that had filled their weekly questionnaire were included in this analysis regardless of reporting, or not reporting any injuries during the follow-up. This means that the players that listed "0 days" of injury absence in the season either: a) had no reported injuries during the season, or b) had reported injuries during the season that didn't result in absence from training.

Median absence for injuries in both groups combined was 2 days (range 0-71 days), and 39.5% of players reported absence for injuries during the season. Median absence for injuries in the season in the group with ACL injury history (n=17) was 6 days (range 0-39) and in this group 29.4% of players did not report any absence for injuries during the season. In the group that had no reported ACL injury history (n=97) the median absence for injuries was 2 days (range 0-71), and in this group 41.2% of the players reported no injury absence on the season.

An independent samples t-test was conducted to compare days off from participation for all MSK injury categories in the National League 2020 season for players with (ACL-group) and without

(control group) the ACL injury history. There was no significant difference in the mean absence for ACL-group (M=9.29; SD=11.08) and control group (M=7.10; SD=13.56) conditions (mean difference=2.19); t(112)=0.630, p = 0.530. According to this, the ACL injury group did not spend significantly more time out from full participation for all injuries in the National League 2020 season than the control group when the p<0.05. The distribution of number of days off from participation for musculoskeletal injuries per group can be seen in the Figure 6.



Figure 6. Number of days off for injuries on the season in groups

Due to a higher number of players, it should be noted that the group with no ACL injury history is potentially more representative of the population than the group with an ACL injury history.

6.5.1 Group absence for injuries in the league season

Injuries during the National League 2020 season were categorized by the requirement of absence. This analysis included injuries that were classified as either minimal (1-3 days), mild (4-7 days), moderate (8-28 days) or severe (>28 days). Pearson's Chi-Square test was used to study if the players that had experienced an ACL-injury experienced injuries that resulted to time off from participation (minimal - severe) during the National League season 2020 more often than the players that had not experienced an ACL injury in the career.

ACL injury in career	0 days absence in 2020	1, or more days absence in 2020	Total
No	40	57	97
Yes	5	12	17
Total	45	69	114

Table 3. Injury absence in groups

6.5.2 Group injury prevalence during the league season

The occurrence of MSK injuries that resulted in one or more days out from participation during the National League season 2020 did not differ by whether the group had or had not experienced ACL-injuries in their career, X2(1, N = 114) = 0.85, p (0.36) >.05. The odds of avoiding MSK injuries that lead to absence from participation during the season in the group without an ACL injury history were 1.7 times higher than in the group that had an ACL injury history (OR 1.7, 95% CI:0.6–5.2). The result though wasn't statistically significant (p > .05) and it is possible that the sample result had occurred by chance. For this reason, the null hypothesis could not be rejected.

Later, the groups were also analyzed (Table 5) by the occurrence of any MSK injury during the National League 2020 season, not dependent on if these required a time out of participation or not. This analysis differed from the earlier analysis by taking also the slight (0 days) injuries into account. Pearson's Chi-Square test was used to study if the players that had experienced an ACLinjury had experienced musculoskeletal injuries more often during the National League season 2020 than the group that had no ACL injury history.

Table 4. Injury prevalence in groups

ACL injury in career	No injuries in 2020	Injury in 2020	Total
Νο	30	67	97
Yes	4	13	17
Total	34	80	114

The occurrence of MSK injuries during the National League season 2020 did not differ by whether the group had or had not experienced ACL-injuries in their career, X2(1, N = 114) = 0.38, p (0.54) > .05. The distribution of injuries regardless of absence can be seen in the Figure 8.



Figure 7. Injury prevalence in groups

The odds of avoiding the occurrence of any MSK injury during the season in the group that had no ACL injury history was 1.5 times higher to the group with an ACL injury history (OR 1.5, 95% CI: 0.4.–4.8), but this result was not also backed with statistical significance (p=0.27). Again, the sample result is possible to have occurred due to chance and the null hypothesis could not be rejected in this research question either. Odds of 2020 injuries with and without absence in the groups can be seen below (Table 6).

	Value	95% CI (Lower)	95% CI (Upper)	Between group
				comparison (p-
				value)
Odds of avoiding (any) injuries in	1.455	0.438	4.834	.270
season 2020 (No ACL history vs.				
ACL history)				
Odds of avoiding injuries (that led	1.684	0.550	5.156	.181
to time loss) in season 2020 (No				
ACL history vs. ACL history)				

Table 5. Odds of injuries in 2020 (No ACL history vs. ACL history)

6.6 Match minute comparison vs. 2020 season injuries

Finally, the players that had experienced any musculoskeletal injury during the National League season 2020 were compared to the players that had not experienced any musculoskeletal injury during the competitive season in regards of their playing minutes in the same season. With this assessment it was desired to know whether musculoskeletal injuries during the League season affect to players playing time in the season.

6.6.1 Match minutes based on injury prevalence

An independent samples t-test was conducted to compare the playing time in the group (n=80) that had experienced 1-, or more MSK injuries (slight – severe) during the season and the group (n=34) that did not report MSK injuries during the 2020 season. There was no significant difference in the playing minutes of the MSK injury group (M=997; SD=532) and no-injury group (M=920; SD=643) during the league season; t(112)=0.665, p = .507.



Any MSK injury in the 2020 National League season

Figure 8. Playing minutes 2020 (injuries vs. no injuries)

After this the interest was on the possible relation of the injury profile on the playing minutes. In the following analysis an independent samples t-test was conducted to compare the playing time in the group (n=69) that had experienced an injury that led to 1- or more days out from the team participation (minimal – severe), and the group (n=45) that either didn't report any injuries or reported injuries that didn't lead to time loss days during the 2020 season. There was no significant difference in the playing minutes of the group that experienced time-consuming injuries (M=987; SD=540) and the group that didn't miss the training / competition days for injuries (M=954; SD=609) during the league season either; t(112)=0.303, p = .763. The results of the independent samples t-test can be seen in below (Table 7).

	Players (114)	Mean play-	SD	Mean difference	Between group
		ing minutes			comparison (p-
					value)
No injuries in 2020	34	920	643	-77	.507
Injury/injuries in 2020	80	997	532	77	.507
No absence for injuries in 2020	45	954	609	-33	.763
Absence for injuries in 2020	69	987	540	33	.763

Table 6. Playing minutes vs. injury prevalence in season 2020

Therefore, whether the player had experienced MSK injuries during the league season was not found to be significantly associated with the amount of playing time during the league season, and for this research question either the null hypothesis could not be rejected. In both assessments, the mean playing time was actually higher for the group that had experienced MSK injuries during the season.

7 Discussion

The main objective in this master's thesis work was to study whether the history of ACL-injury in women's player affects her career in the top-level football in comparison to players without ACL-injury history. According to this study the ACL-injured players of the Finnish National League played nearly three matches (255 minutes) less during the 2020 National League season in all competitions in relation to the players that participated without an ACL-injury history. Similarly, to the study of Forsythe and colleagues (2021) on elite male football, in this study the players with ACL injury history also played less minutes in the further season after their injury in relation to the players and the finding goes hand in hand with other performance findings from male football (Forsythe et al. 2021; Niederer et al., 2018).

The results of the additional research questions showed similarity to the male football studies as there was no connection found between ACL-injury history and further musculoskeletal injuries (Niederer et al., 2018). With the results of this study, it can't be concluded that personal injury prevalence during the season would be an explanatory factor for the playing time in the season either, as also the majority of the injuries in the season resulted in max 3 days out from the participation. It is possible that with many minor injuries the players are rested from sessions for good measure to make sure they can play in the games, as it is also likely that the players are simply able to play regardless of some minor injuries. The deviation of the playing time was all in all high as the standard deviation of the total minutes during the National League season was 5-7 full games among players. It can be discussed if the odds for avoiding an absence injury in season without ACL injury history could have turned closer to significant if the ACL injury history group would have had as high number of participants as the group without ACL injury history. It can also be discussed if a person that has suffered / gone through a rehabilitation for an injury in a vicinity of an ACL tear is more conscious for reporting further injuries with lower threshold in the study. For two teams in the league, it was not possible to do the season injury analysis as these teams used a different method in recording the injuries, and this limits the generalization of the later research questions to the whole league.

With a statistically significant difference in the playing minutes of two groups the possible reasons for these results should be discussed. Potentially decreased playing minutes after an ACL injury might be due to lower functional capabilities after the ACL recovery and be supported by studies that have found out that the rehabilitation of the ACL can leave a lower function and muscle weakness in the flexor and extensor muscles of the knee in a longer term after the rehabilitation (Grindem et al., 2014). The season 2020 in the National League was exceptional as the start of the season was delayed for the COVID-19 pandemic for over 2 months, and the team and gym training abilities were limited for few months in the crucial parts of the pre-season period of the spring 2020. The limitations in the training abilities and changes in the training plans in this data assessment season for different teams were obvious and that could hypothetically have influenced to building physical readiness and preventing injuries during the further season. It can be discussed whether the limitations in the possibility of training e.g., football and strength appropriately in the preseason has hindered more of the performance of the players with ACL-injury history. It is also possible that some teams handled the additional >2 months pre-season more effectively than others from the physical preparation and injury prevention point of view. To demonstrate the possible reaction to the COVID-19 statutes, in the top women's league in Sweden there were already 12 ACL injuries reported among seven teams after the first five league matches in mid-July 2020 (Waldén et al., 2020).

The preseason playing minutes are also not involved in the assessment of this study. Teams were able to play training matches and majority of the Finnish Cup campaign during the January – March – period, but the late preseason training matches along with Finnish Cup semi-final matches were in pause for a while because of the COVID-19 pandemic from the 13th of March and many teams did not have time to play competitive matches acutely before the start of the season. Concerning the results in this thesis, the effect of the training match involvement to the league season involvement must be considered. In the assessment of the main research question there could have been players with an ACL injury history that had under 12 months from their latest ACL injury by the time that the main preseason matches were played in the January – March 2020. If the player has not played many preparatory matches after the long injury in the winter-spring period, it can also more probably affect on the involvement in the further games for later than the set limit of 12 months, in other words the start of the league campaign in June 2020 as well. Due to the fact that the season 2020 in National League was also shortened in the number of games because of the COVID-19 season delay it can be also asked whether the included players that had experienced their ACL injury the most recently would have played more minutes if the season would have been played in full scale. Studying whether the playing minutes of the ACL group grew along the season could have been revealing for these mentioned discussions.

Arguably the participating players that are still playing in the highest level in Finland can be seen as the side of the most efficiently rehabilitated individuals among the ACL-injured players, as it is highly likely that certain number of players have been forced to end career or play in a lower level after this injury (Fältström et al., 2019; Niederer et al., 2018; Read et al., 2017). The players that have ended their careers or moved to play in a lower level because of their ACL injury process are not visible in this study which is a factor that potentially highlights the playing minute difference. It can be argued that if a higher percentage of the unknown players that have possibly retired from top level (quit playing or playing in the lower level) after their ACL injury would have been involved in the National League 2020 assessment after all, this playing minute difference would not have moderated.

7.1 Strengths, weaknesses, and reliability of the study

The strength of this study is that the collected data is based on sources that are arguably reliable especially for the main outcome measurements (reported ACL injury history & FA Finland match minute database). For the severity of an ACL-injury it may be assumed that a player reports the injury history and remembers timing for that injury reliably. Also, vast majority of the matches played during the competitive season are official matches and therefore majority of the individual match minutes can be found from the FA Finland database reliably. Possible inaccuracy in the personal injury reporting (e.g., reporting of players and team physiotherapists) during the season is a prominent limiting factor in the analysis of other research questions that include analyzing of the season 2020 injuries.

The football players in the National League are mainly semi-professionals, and weekly answering to the questionnaire might have been seen as an extra burden for some players. The players had to spend more time answering the questions if they reported any new issues, and during a long year it is possible that some, at least more minor injuries, have not been added to the questionnaire for time saving reasons. Nevertheless, the weekly answering percentage stayed high for the whole season in this study.

Usually in similar studies to this a major limitation is the retrospective data collection procedure in the collection of the player injury history that can lead to insufficient data-accuracy or a certain amount of recall bias. In this study the only questionnaire details that affected the results of the main research question were the occurrence of ACL-injury (yes/no) and the date of the occurrence which are most likely easy to remember for the participant.

With used methods and conditions this study can be reproduced again in the upcoming years for a further follow-up in Finland. A similar study is also possible to repeat and produce in other countries that have reliable sources for the personal playing minute analysis.

One limiting factor in the evaluation of this thesis study can be argued to be the student's involvement in the team staffs of two different National League teams during the writing of this thesis in 2021 & 2022 seasons. In the data collection season (2020) of this thesis though, there was no mentioned involvement in any of the participating teams. Data of the participating players of competing teams was handled with good convention and safety and not used for the benefit of single teams in the later time, and the student's involvement in the National League action during the writing process can't be determined as a conflict of interest for this research.

8 Conclusions

The burden of a single ACL-injury for the year after the incidence is obvious and according to this study it might affect on the playing time in the later playing years as well in Finnish top league level. According to the study the ACL-injuries in elite women's football account for high percentage of all absence from the sport and seem to be related to further declined performance in terms of playing minutes per season. This burden in women's football needs more high-quality research and consensus behind the everyday decisions in prevention, rehabilitation, and return-to-performance in the football teams and external environments that are involved in women athlete's development.

78% of the ACL injuries seen in the data of this study were non-contact injuries. The staff, including e.g., coaches and fitness/medical professionals have a main responsibility to help reduce injuries by critically reviewing the season planning and overall load on players, and at the same time utilize good rehabilitation protocols to make sure that players can return safely to full competition (Hägglund el al., 2009). The first steps in Finnish football could involve a development of co-operation between the coaches and staffs in the football league on good conventions in these topics, and financial support for the development of physical therapy and performance units inside teams to have a more time to tackle these specific issues inside a single team in e.g., an individual player level. In a lower budget league, like the Finnish National League the understanding of the possible price of a single injury for the team is also crucial. For a single team it is arguably advantageous to invest in prevention and well-working rehabilitation/medical team for their players. ACL injury for the rehabilitation length and thigh muscle & ankle ligament injuries for the high prevalence are among injuries that should be taken in account when planning of women's football team prevention programs and training. A factor that should motivate for action along with the seen results is that from the team performance point of view, a significant association between decreased team injury incidence and increased success in domestic and European cups has been already demonstrated in elite male football (Hägglund et al., 2013).

A relatively long pre-season (4-6 months) in Finland gives advantageous opportunities to build and program physical preparation progressively before the start of the competitive season during which a possibly higher match exposure puts women players under higher risk of the occurrence of ACL injuries, as concluded from the initial data. Arguably, this long pre-season can also be a risk for a lot lower game exposure than during the intensive competitive season schedule. As found in this study, a high amount of the injuries (67% of ACL-injuries in the history) occurred in the match-play where the requirements for the high-performance rise. Similar results have also been found from systematically in women's football (López-Valenciano et al., 2021; Waldén et al., 2011). It needs to be discussed if the woman players are currently getting enough physical exposure similar to matches during the weekly & yearly training to get better "vaccinated" for these injuries in games. On the other hand, it is also found that the match injury incidences are higher in the top five ranked leagues vs the lower-level leagues, and the high injury rate can therefore also mirror to e.g., a higher speed and explosive action exposures in the higher performance level (López-Valenciano et al., 2021; Bradley & Scott., 2019).

This study discussed that in the women's elite football also the return to performance after a longterm injury like ACL tear can't usually be taken for granted. These could be messages to coaching and technical/medical staffs, and boards of clubs to put efforts in preventing and rehabilitating injuries in the chase of a successful team performance. The prevention strategies of ACL injury along with progressive manners of best current knowledge and well-structured return-to-play assessment are vital to tackle this burden in women's football. During a long rehabilitation period of ACL injury, it is important for the staff and professionals involved in the rehabilitation to give their best mental support for the injured women's players as well for maximizing a motivating and meaningful training time outside of full team participation. During the rehabilitation the injured player would benefit from multi-professional team where the development of players physical abilities required for football are efficiently and safely developed parallel to the rehabilitation of the knee, and this highlights the importance of co-operation between team staff and other professionals who work with the injured player. The physiotherapists involved in the rehabilitation of elite players in Finland may be external or internal to the team environment, and it is important to share clear information of the loading and limits of the injured or returning player between coaches and the involved physiotherapists.

8.1 Further study of the topic

In the question of "how well has the player recovered from her ACL injury?", along with the reinjury rate and functional/pain outcomes, a playing time in the further seasons can be seen as a reasonable and straightforward measure for recovery that a football player is likely to be interested in too. Optimally, the question of "how much have the ACL-injured players played in the seasons before their ACL injury?" could also be one way to look at to see whether the players have personally reached the playing minutes they used to play before the injury rather than comparing solely to other players without ACL injury history. A challenge with this though is that it would bring more confounding factors to the assessment of this study, like the fact that the ACL injury data includes a lot of players that have sustained their injury in the first season of playing in the National League, as well as players that have sustained more than one ACL injury.

In the shortage of the widely accepted criteria for "when the player has recovered well from his/her ACL injury to football performance?" the playing minutes in further years can be considered a meaningful rehabilitation timeline measure for the player as well when planning rehabilitation. The validity of high / low playing minutes as a measure for structural and functional ACL injury recovery could be studied in the future, as one option could be to study this also in parallel with re-injury rates and performance parameters.

In the future, the research of performance parameters after the ACL rehabilitation in women could benefit from widening into also other variables that measure the level of performance in the

game, like goals scored, chances created/blocked or high-speed actions produced after the rehabilitation. Data analysis of the game is developing rapidly, and new parameters for player & team actions during the game with and without the ball for the assessment of player performance are rising. This will also give opportunities to more valid assessment of playing position related rehabilitation to performance after injuries in the future.

In the future, the ACL-injuries, and a risk for further injuries in women could be approached in a more categorial way of the further injuries to see if there is an orientation to similar injury location profiles after the ACL rehabilitation in comparison to un-injured. The assessment of further injuries after an ACL injury could include more seasons after the rehabilitation than one.

It can also be argued that if a player plays more league minutes during the year, he/she could automatically be exposed for the high loading game situations & strain more often than e.g., the non-starters which could act as a protective effect for sustaining an ACL injury. It has been shown that the non-starters can potentially be underloaded during the football season regarding the optimal training load (Calderón-Pellegrino et al., 2022). The careers before the ACL injury in regards of e.g., the playing minutes before and after would be an interesting topic to study in the future.

As it was concluded from the results, there is a lot of space in the future for the high-level studies and consensus statements on the stages and contents of the ACL injury rehabilitation to football for it to be clearer for also the physiotherapists working in this sector. As serious knee injuries are clearly a burden of greater extent in women's football, it would be ideal, rather than merely comparing men's and women's athletes, to see the research dig deeper in this topic to the larger context of women's sports, it's evolution, athlete's growth environments and sociocultural development.

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Appendices

Appendix 1. Weekly health questionnaire

Weekly health questionnaire (Finnish Football Injury Study, Tampere Research Center of Sports Medicine, UKK Institute)

Question 1 - Participation

1) * Have you had any difficulties participating in normal training and competition due to injury, illness or other health problems during the past 7 days?

- C Full participation without injury/illness
- C Full participation, but with injury/illness
- C Reduced participation due to injury/illness
- Could not participate due to injury/illness

Question 2 - Modified training/competition

2) * To what extent have you modified your training or competition due to injury, illness or other health problems during the past 7 days?

- C To a minor extent
- C To a moderate extent
- C To a major extent
- Could not participate at all

Question 3 - Performance

3) * To what extent has injury, illness or other health problems affected your performance during the past 7 days?

- C To a minor extent
- C To a moderate extent
- C To a major extent
- C Could not participate at all

Question 4 - Symptoms

4) * To what extent have you experienced symptoms/health complaints during the past 7 days?

C To a mild extent

- C To a moderate extent
- C To a major extent
- C Could not participate at all

5) * Is the health problem referred to in the four questions above an injury or an illness?

- C Injury (acute injury, overuse injury or complaint, concussion/head injury)
- C Illness

6) * Is this

- C new injury (this is the first time I report this injury USING THIS SYSTEM)
- ^C old injury (I have reported this injury earlier USING THIS SYSTEM)

7) * Date, when the injury occurred, or the symptoms began

8) * Onset of injury

- C Acute
- C Overuse (gradual onset)

9) * Injured body part

- C Head
- C Face
- C Neck/cervical spine
- C Shoulder/clavicle
- C Upper arm
- C Elbow
- C Forearm
- C Wrist
- C Hand/finger
- C Chest/sternum/ribs
- C Upper back
- C Lower back/sacrum
- C Abdomen
- C Pelvis
- C Hip
- C Groin
- C Buttock

- C Thigh/quadriceps
- Thigh/hamstring
- C Knee
- C Lower leg
- C Achilles
- C Ankle
- C Foot/toe
- C Other, what?

10) * Injured body side

- C Left
- C Right
- C Both
- C Not applicable

11) * Where did the injury occur?

- C National League match
- C Finnish cup match
- C National team match
- C Unofficial/friendly match
- C Football training
- C Supportive or conditioning training
- C Other than sports (other accident)
- C Other, where?

12) * Surface

- C Grass
- C Artificial turf
- C Wooden
- C Artificial indoor
- C Other, specify

13) * Have you had a previous injury of the same type at the same site (i.e. this injury is a recurrence)?

- C No
- C Yes, specify date of return to full participation from the previous injury (dd.mm.yy)

14) * Was the injury caused by contact or collision?

- C No
- C Yes, with another player
- C Yes, with the ball
- C Yes, with other object, specify

15) * Type of contact

- C Direct contact to the injured body part
- C Indirect contact (contact to other than the injured body part), specify

16) * Injury situation

- C Running/sprinting
- C Sudden stop
- C Change of direction
- C Dribbling
- C Jumping/landing
- C Shooting
- C Falling/sliding
- C Tackled by another player
- C Tackling another player
- C Collision
- C Hit by ball
- C Kicked by another player
- C Heading
- C Hit by arm/elbow
- C Stretching
- C Other, specify

Please select the major symptoms you have experienced during the past 7 days. You may select several alternatives; however, in the case that you have several unrelated illnesses please complete a separate registration of each one.

19) * Symptoms

□Fever□Fatigue/malaise□Swollen glands

□Sore throat □Blocked nose/running nose/sneezing □Cough □Breathing difficulty/tightness □Headache □Nausea □Vomiting Diarrhoea □Constipation □Fainting □Rash/itchiness □Irregular pulse/arrhytmia □Chest pain/angina □Abdominal pain □Other pain □Numbness/pins and needles □Anxiety □Depression/sadness □Irritabililty □Eye symptoms □Ear symptoms □Symptoms from urinary tract/genitalia □Other, specify Time loss

20) * Please state the number of days over the past 7-day period that you have had to COMPLETELY miss training or competition due to this problem?

 \circ $_{0}\circ$ $_{1}\circ$ $_{2}\circ$ $_{3}\circ$ $_{4}\circ$ $_{5}\circ$ $_{6}\circ$ $_{7}$

21) Diagnosis (if known)

23) * Have you experienced any other illnesses, injuries or other health problems during the past 7 days?

C No

C Yes

Appendix 2 Background questionnaire (ACL-relevant questions)

Background questionnaire (Finnish Football Injury Study, Tampere Research Center of Sports Medicine, UKK Institute)

•••

129. Have you ever suffered from an anterior cruciate ligament (ACL) injury of the knee? *

No

Yes, right knee

Yes, left knee

Yes, both knees

The following questions concern your previous ACL injury. If you have had more than two ACL

injuries, please report the first two injuries separately.

130. ACL injury 1: When the ACL injury occurred? If you cannot remember the exact date, please select the year and choose the 15th of the month. *

dd.mm.yyyy

131. ACL injury 1: Was your knee operated? *

No

Yes

132. ACL injury 1: Where did the ACL injury occur? *

in an official match

in an unofficial match

in a football training

in a supportive training (such as strength training)

somewhere else

133. Somewhere else, where? *

134. ACL injury 1: Was the injury caused by external contact or collision (such as tackling, pulling, tripping, or contact with the ball)? *

No

Yes

Unable to say

135. ACL injury 1: Was the injury caused by a direct hit to the knee? *

No

Yes

Unable to say

136. ACL injury 1: What was the injury mechanism? *

jumping/landing

sudden stop

direction change

dribbling

kicking

other

unable to say

137. Other mechanism, specify *

138. ACL injury 1: Have you suffered from other ACL injuries, besides the one you already reported? *

No

Yes

139. ACL injury 2: When the ACL injury occurred? If you cannot remember the exact date,

please select the year and choose the 15th of the month. *

dd.mm.yyyy

140. ACL injury 2: Was your knee operated? *

No

Yes

141. ACL injury 2: Where did the ACL injury occur? *

in an official match

in an unofficial match

in a football training

in a supportive training (such as strength training)

somewhere else

142. Somewhere else, where? *

143. ACL injury 2: Was the injury caused by external contact or collision (such as tackling, pulling, tripping, or contact with the ball)? *

No

*

Yes

Unable to say

144. ACL injury 2: Was the injury caused by a direct hit to the knee? *

No

Yes

Unable to say

145. ACL injury 2: What was the injury mechanism? *

jumping/landing

sudden stop

direction change

dribbling

kicking

other

unable to say

146. Other mechanism, specify? *